Fishery Data Series No. 94-5

Stock Status and Rehabilitation of Chena River Arctic Grayling During 1993

by

Robert A. Clark

July 1994

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STOCK STATUS AND REHABILITATION OF CHENA RIVER ARCTIC GRAYLING DURING 1993[1]

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[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-9, Job No. R-3-2(a).

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

Stock status of Arctic grayling *Thymallus arcticus* in the lower 152 kilometers of the Chena River was described by population abundance, age composition, size composition, recruitment, and survival rate estimates during 1993. In July of 1993, estimated abundance of Arctic grayling in the Chena River was 39,618 fish (SE was 4,836 fish) ≥ 150 millimeter fork length. Age 3 Arctic grayling were strongly represented in the Chena River, representing 48.1 percent of fish ≥ 150 millimeter fork length. Stock size Arctic grayling (≥ 270 millimeter fork length) represented 78.8 percent of fish ≥ 150 millimeter fork length. Annual recruitment between 1992 and 1993 was 19,066 Arctic grayling (SE was 2,647 fish) and annual survival during this period was 60.1 percent (SE was 6.2 percent). Although recruitment in 1993 was the largest observed recruitment since 1986, below average recruitment is expected in 1994 and 1995.

On 1 through 11 June 1993, 64,936 hatchery-reared Arctic grayling (1992 brood year) were released at seven locations along the lower 160 kilometers of the Chena River. Mean fork length prior to release was 212 millimeters (SD was 22 millimeters) and mean weight was 97 grams. Estimated abundance of these fish in the lower 152 kilometers of the river during July 1993 was 33,061 fish (SE was 3,190 fish) ≥ 150 millimeters fork length. Abundance of hatchery-reared fish in July 1993 accounted for 45.5 percent of total abundance (wild plus hatchery fish). Mean fork length of hatchery produced fish was 217 millimeters (SD was 21 millimeters) in July 1993. No pond-reared fish, released in 1992, were captured during stock assessment.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, electrofishing, population abundance, age composition, size composition, Relative Stock Density, recruitment, survival rate, rehabilitation, hatchery releases, Chena River.

INTRODUCTION

Background

The Chena River once supported the largest Arctic grayling fishery in North America. For the 14 year period from 1979 to 1992, the Chena River produced an average annual sport harvest of 13,840 Arctic grayling. Average angling effort for all species of fish during this period was 25,022 angler-days (Table 1). As recently as 1984, annual harvests had exceeded 20,000 fish and 30,000 angler-days of effort (all species), and harvests of Arctic grayling from the Chena River comprised a substantial portion of total Arctic grayling harvests in the Tanana River drainage (Figure 1). However, the status of this fishery has changed since 1984. Recreational harvest of Arctic grayling has declined to historic low levels. Harvest decreased 76% from 1984 to 1985, although angling effort had decreased only 39% (Table 1). Angling effort returned to an average level in 1986, but harvest remained below 10,000 fish. Concomitant with the declining recreational fishery was the decline in Arctic grayling population abundance. Stock assessment projects during 1986 (Clark and Ridder 1987b) and 1987 (Clark and Ridder 1988) documented a decline in population abundance of 49% between these two years. Poor recruitment was the probable cause for a decline in abundance (Holmes 1984, Holmes et al. 1986, Clark 1992a).

During the winter of 1986, fishery managers were scheduled to present stock status data (Clark 1986) on the Chena River fishery to the Alaska Board of Fisheries. The Board of Fisheries meeting adjourned before the data could be presented. In spring of 1987, increased concern for the health of the Chena River stock prompted fishery managers to process emergency regulations to reduce harvest. These emergency regulations were:

1) closure of the fishery from 1 April until the first Saturday in June;

2) a 12 inch (305 mm) minimum total length limit; and,

3) restriction of terminal gear to unbaited artificial lures.

These emergency regulations were made permanent regulations in the summer of 1987. During the winter of 1987, fishery managers presented stock status and regulatory concerns to the Alaska Board of Fisheries (Clark 1987). The emergency regulations imposed in spring of 1987 were adopted and amended. The new permanent regulations were:

1) catch-and-release fishing from 1 April to the first Saturday in June;

2) a 12 inch (305 mm) minimum total length limit from the first Saturday in June until 31 March;

Table 1. Summary of total angling effort and Arctic grayling harvest on the Chena River, 1977-1992 (taken from Mills, 1979-1993).

	Lower Chena River[a]		Upper Chena River[b]		Entire Chena River	
Year	Angler-days	Harvest	Angler-days	Harvest	Angler-days	Harvest
1977[c]	---	---	---	---	30,003	21,723
1978[c]	---	---	---	---	38,341	33,330
1979	9,430	11,290	8,016	11,664	17,446	22,954
1980	13,850	18,520	10,734	16,588	24,584	35,108
1981	11,763	10,814	10,740	13,735	22,503	24,549
1982	18,818	11,117	15,166	12,907	33,984	24,024
1983	17,568	7,894	16,725	10,835	34,293	18,729
1984	20,556	13,850	11,741	12,630	32,297	26,480
1985	11,169	2,923	8,568	3,317	19,737	6,240
1986	18,669	4,167	10,688	3,695	29,357	7,862
1987[d]	12,605	1,230	10,667	1,451	23,272	2,681
1988[d,e]	16,244	2,686	9,677	1,896	25,921	4,582
1989[d,e]	20,317	7,194	10,014	5,441	30,331	12,635
1990[d,e,f]	18,957	3,494	6,949	945	25,906	4,439
1991[d,e,f,g]	12,547	2,997	8,591	722	21,138	3,719
1992[h]	7,671	0	4,983	0	12,654	0
Averages[i]	14,789	6,995	10,233	6,845	25,022	13,840

[a] Lower Chena River is from the mouth upstream to 40 km Chena Hot Springs Road (Mills 1988). In 1991 and 1992, the Lower Chena River included Badger Slough. Angling effort is for all species of fish.

[b] Upper Chena River is the Chena River and tributaries accessed from the Chena Hot Springs Road beyond 40 km on the road (Mills 1988). Angling effort is for all species of fish.

[c] Angler-days and harvest are computed for the Chena River <u>and</u> Badger Slough.

[d] Special regulations were in effect during 1987 through 1991. These regulations were: catch-and-release fishing from 1 April until the first Saturday in June; a 305 mm (12 inch) minimum length limit; and, a restriction of terminal gear to unbaited artificial lures.

[e] In addition to the special regulations, a catch-and-release area was created on the Upper Chena River (river km 140.8 to 123.2).

[f] The daily bag and possession limits were reduced from five fish to two fish in 1990.

[g] During 1991, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 July through 31 December.

[h] During 1992, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 January through 31 December.

[i] Averages are for 1979 through 1992 only.

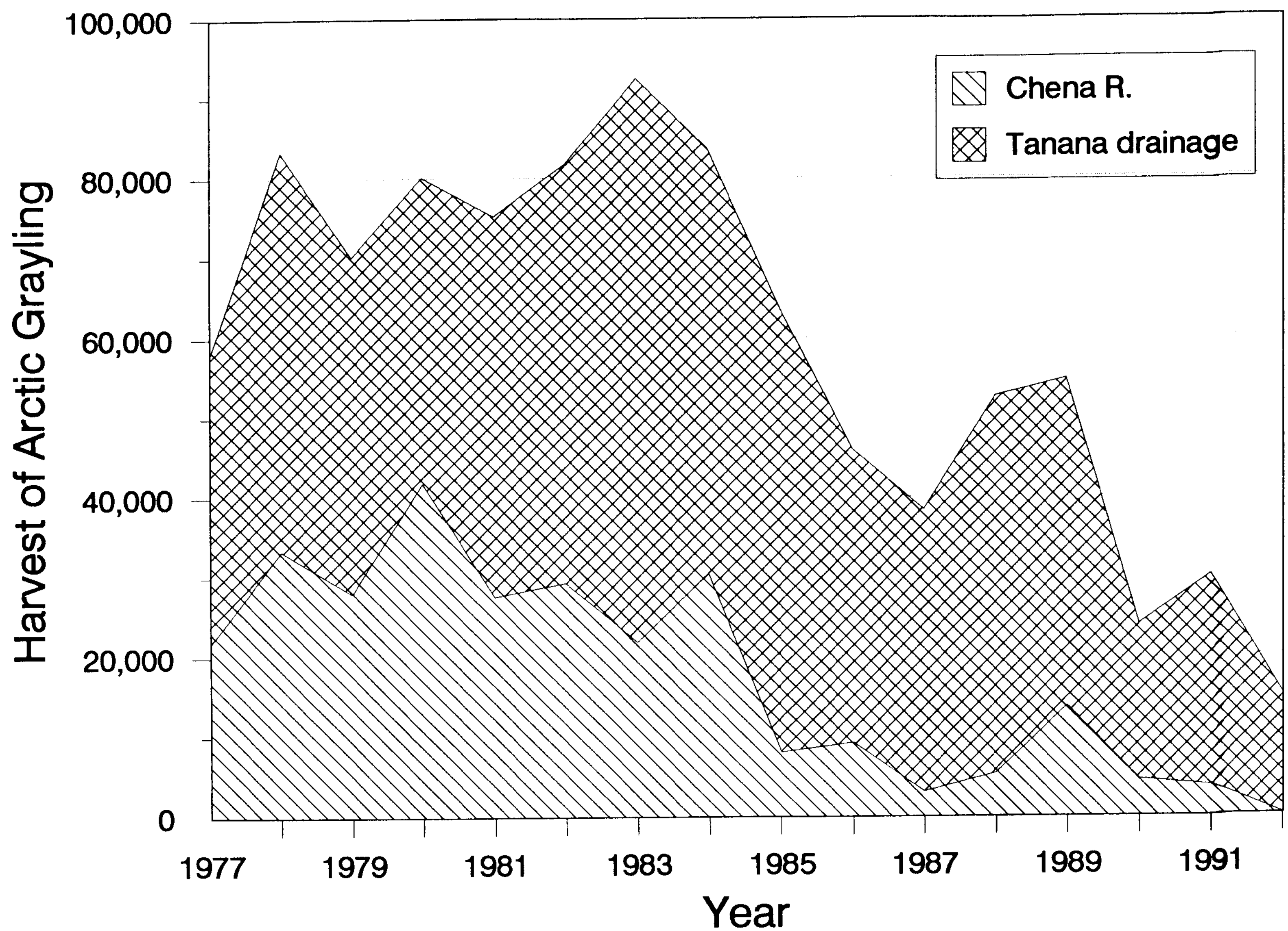

Figure 1. Annual harvests of Arctic grayling in the Chena River and in the entire Tanana River drainage, 1977-1992 (taken from Mills 1979-1993).

3) restriction of terminal gear to unbaited artificial lures only throughout the Chena River, and bait fishing allowed downstream of the Moose Creek Dam with hooks having a gap larger than 0.75 inch (19 mm);

4) catch-and-release fishing year around from river kilometer 140.8 downstream to river kilometer 123.2; and,

5) reduce the possession limit from 10 to 5 fish (Tanana River drainage-wide regulation).

The regulations adopted by the Board of Fisheries in winter of 1987 were the first changes in Arctic grayling management since 1975, when the daily bag limit was decreased from 10 to 5 fish. Evaluation of the effects of new regulations on the Arctic grayling stock and recreational anglers was begun in 1987.

In 1990, continued concern for the Arctic grayling stock in the Chena River prompted the Board of Fisheries to implement a daily bag limit of two fish, riverwide, and single hook regulations upstream of the Moose Creek Dam. On 1 July of 1991, fishery managers invoked Emergency Order authority to reduce the daily bag limit to 0 fish in the entire Chena River drainage. This Emergency Order remained in effect through 1993.

Concomitant with a daily bag limit of 0 fish, fishery managers began a rehabilitation program for Arctic grayling in the Chena River. The rehabilitation program has two main parts: regulation changes to ensure adequate protection of the stock, and a program of supplementation of natural production with releases of hatchery and pond-reared Arctic grayling. The proposed rehabilitation effort will last two years, after which, fishery managers will enact fishery regulations to ensure sustained harvests of Arctic grayling. Beginning in spring of 1992, the first lot of fertilized eggs were taken from the Chena River stock for use in supplementing natural production. During 1993 a second lot of fertilized eggs were taken and 64,936 (97 g fish from the 1992 brood year) were stocked into the Chena River from Clear Hatchery. Stock assessment of Arctic grayling in 1993 focused on separation of hatchery fish from wild fish for estimation of abundance, and size composition.

<u>Objectives for Stock Assessment</u>

In order to accurately and precisely describe the stock status of Arctic grayling in the Chena River, the following objectives were addressed in 1991 and 1992:

1) to estimate the abundance of wild Arctic grayling $\geq$ 150 mm fork length (FL) in the lower 152 km of the Chena River;

2) to estimate the age composition of wild Arctic grayling in the lower 152 km of the Chena River;

3) to estimate the size composition of wild Arctic grayling in the lower 152 km of the Chena River; and,

4) to estimate the proportion of Arctic grayling ≥ 150 mm fork length in each of three groups (wild fish, age 1 hatchery releases, and age 1 pond-reared releases) in the lower 152 km of the Chena River.

In addition to these primary objectives, recruitment of new fish to the stock, the annual survival rate of the stock, abundance of age 1 hatchery releases, size composition of age 1 hatchery releases, and survival of age 1 hatchery releases from release in June until assessment in July were estimated.

METHODS

Hatchery-Reared Fish

As part of the rehabilitation of the Chena River stock, age 1 hatchery-reared Arctic grayling were finclipped and released in seven locations along the Chena River during 1 through 11 June 1993 (Figure 2). Prior to release (1 through 4 March 1993) each fish was marked by complete removal of the left ventral fin. Again prior to release (13 May 1993), a sample of 306 fish was taken with each fish checked for a recognizable fin clip, a sample of scales taken from 120 of the sample, and fork length measured to the nearest 1 millimeter. For release, fish were transported in four aerated holding tanks mounted to a flat-bed truck. Number of fish to be released was estimated at the hatchery by weighing lots of fish as they were loaded into the holding tanks. The average weight of a subsample of fish was used to convert total weight of fish loaded into number of fish. Water in the transport tanks was treated with 8 g of methane sulfonate (MS-222) per tank. Each tank was aerated with oxygen to supersaturation during transport. Upon arrival at the release location, aeration was halted in each tank until oxygen concentration declined to between 90% and 100% saturation. Fish were then released into areas of backwater or eddy in the river. Water temperature of the holding tanks and the river were taken during release. Immediate mortalities or problems with transport were noted.

Sampling Gear and Techniques

During 1993, all sampling was performed with pulsed-DC (direct current) electrofishing systems mounted on 6.1 m long river boats as previously described by Lorenz (1984). Input voltage (240 VAC) was provided by a 3,500 or 4,000 W single-phase gas powered generator. A variable voltage pulsator (Coffelt Manufacturing Model VVP-15) was used to generate output current. Anodes were constructed of 16.0 mm diameter and 1.5 m long twisted steel cable. Four anodes were attached to the front of a 3 m long "T-boom" attached

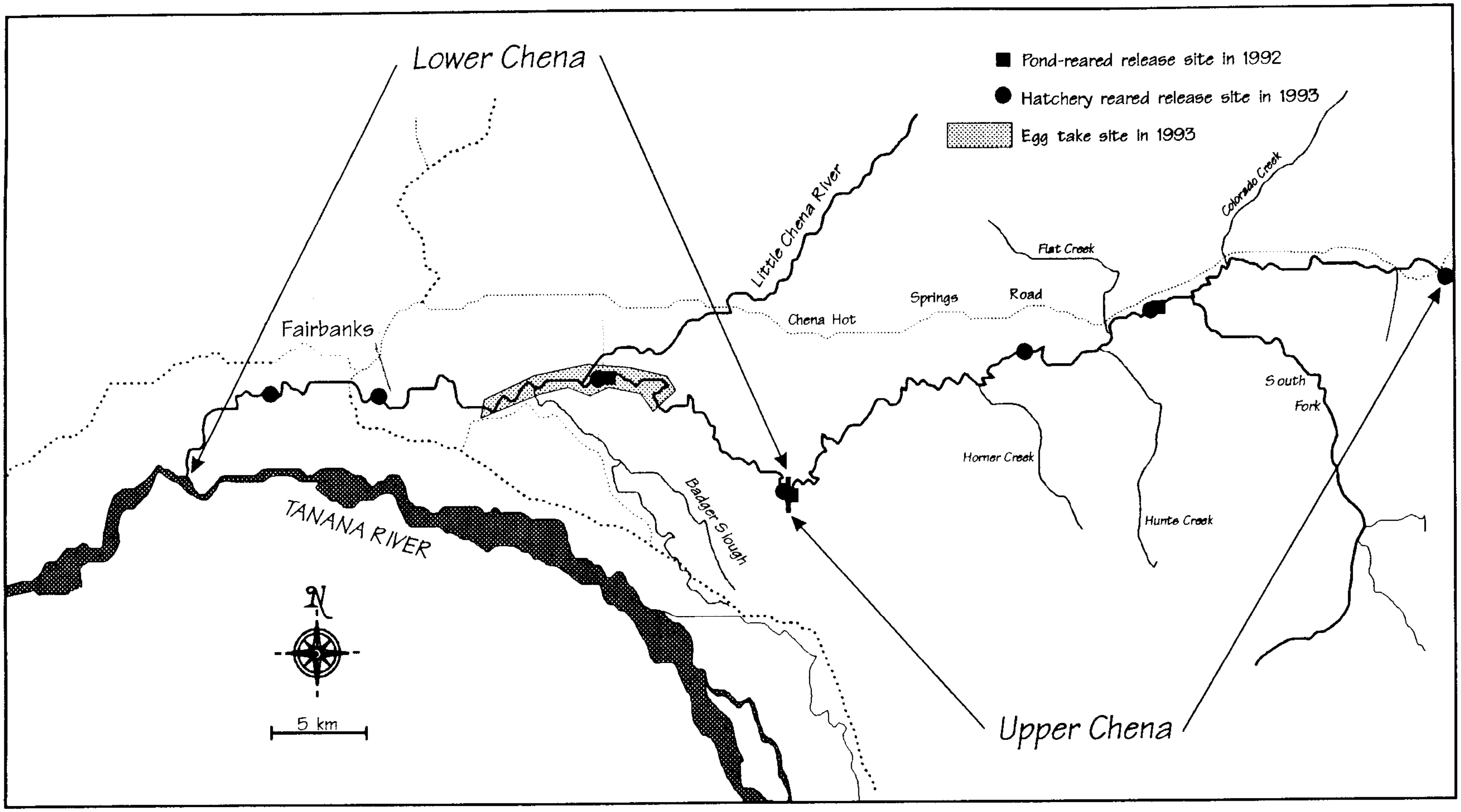

Figure 2. Stock assessment sections in 1993, egg take site in 1993, pond-reared release sites in 1992, and hatchery-reared release sites in 1993 along the lower 152 km of the Chena River drainage.

to a platform at the bow of the river boat. The aluminum hull of the river boat was used as the cathode. Output voltages during sampling varied from 200 to 300 VDC. Amperage varied from 2.5 to 4.0 A. Duty cycle and pulse rate were held constant at 50% and 60 Hz, respectively. These operating characteristics were presumed to minimally affect Arctic grayling survival during mark-recapture experiments. Water conductivity was 180 μS (at 25°C) during electrofishing.

Sampling was conducted along the banks of the Chena River. Two electrofishing boats were each directed downstream along one bank, capturing all Arctic grayling seen, when possible. Captured Arctic grayling were held in an aerated holding tub to reduce capture related stress. The two river sections were sampled no more than once per day to prevent changes in capture probabilities of marked fish (Cross and Stott 1975). Each Arctic grayling was measured to the nearest 1 mm FL. During the second event of the mark-recapture experiments, a sample of scales was taken from an area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin of each wild Arctic grayling. During the same event, a sample of scales was taken from the same area of 120 hatchery-reared enhancement fish. Arctic grayling ≥ 150 mm FL were marked with individually numbered Floy FD-68 internal anchor tags inserted at the base of the dorsal fin. An upper caudal punch was applied for the Lower Chena section and a lower caudal punch was applied for the Upper Chena section to identify marked fish in case the numbered tag was shed. All enhancement fish (hatchery and pond-reared releases) were marked with a complete fin clip (complete left ventral for hatchery and adipose for pond-reared releases) prior to release. If any captured Arctic grayling exhibited signs of injury or imminent mortality, they were immediately sacrificed.

Estimation of Abundance

The abundance of Arctic grayling ≥ 150 mm FL was estimated by mark-recapture techniques in the lower 152 km of the mainstem Chena River (Figure 3). Two sections of the Chena River were delineated for separate estimation experiments. Delineation of the Chena River was necessary because of differences in capture probability of Arctic grayling in different sections of river (Figure 4). Based on differences in capture probability from downstream to upstream areas of the Chena River, the lower 152 km of the Chena River is divided into Lower and Upper sections for estimating abundance and age composition. Downstream from the Moose Creek Dam complex to the mouth of the Chena River was designated the Lower Chena section (72 km long; Figure 2). Upstream from the dam to the first bridge on the Chena Hot Springs Road (river kilometer 62.4) was designated the Upper Chena section (80 km long; Figure 2). Population abundance estimates pertain only to these two sections of the Chena River, excluding Badger Slough, the Little Chena River, and the South Fork of the Chena River.

Abundance of Arctic grayling ≥ 150 mm FL was estimated with the modified Petersen estimator of Bailey (1951, 1952). Two electrofishing boats were used

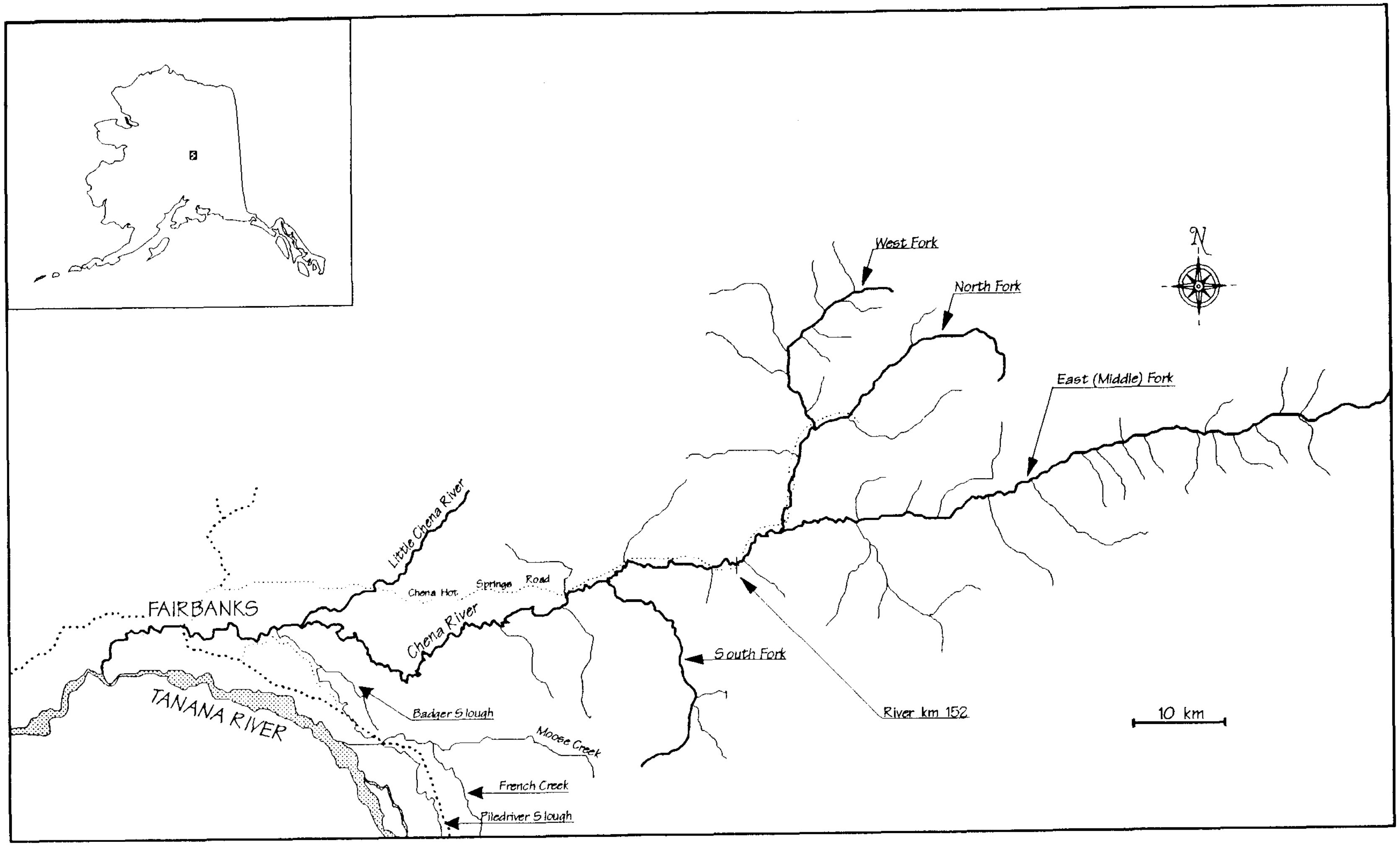

Figure 3. The Chena River drainage.

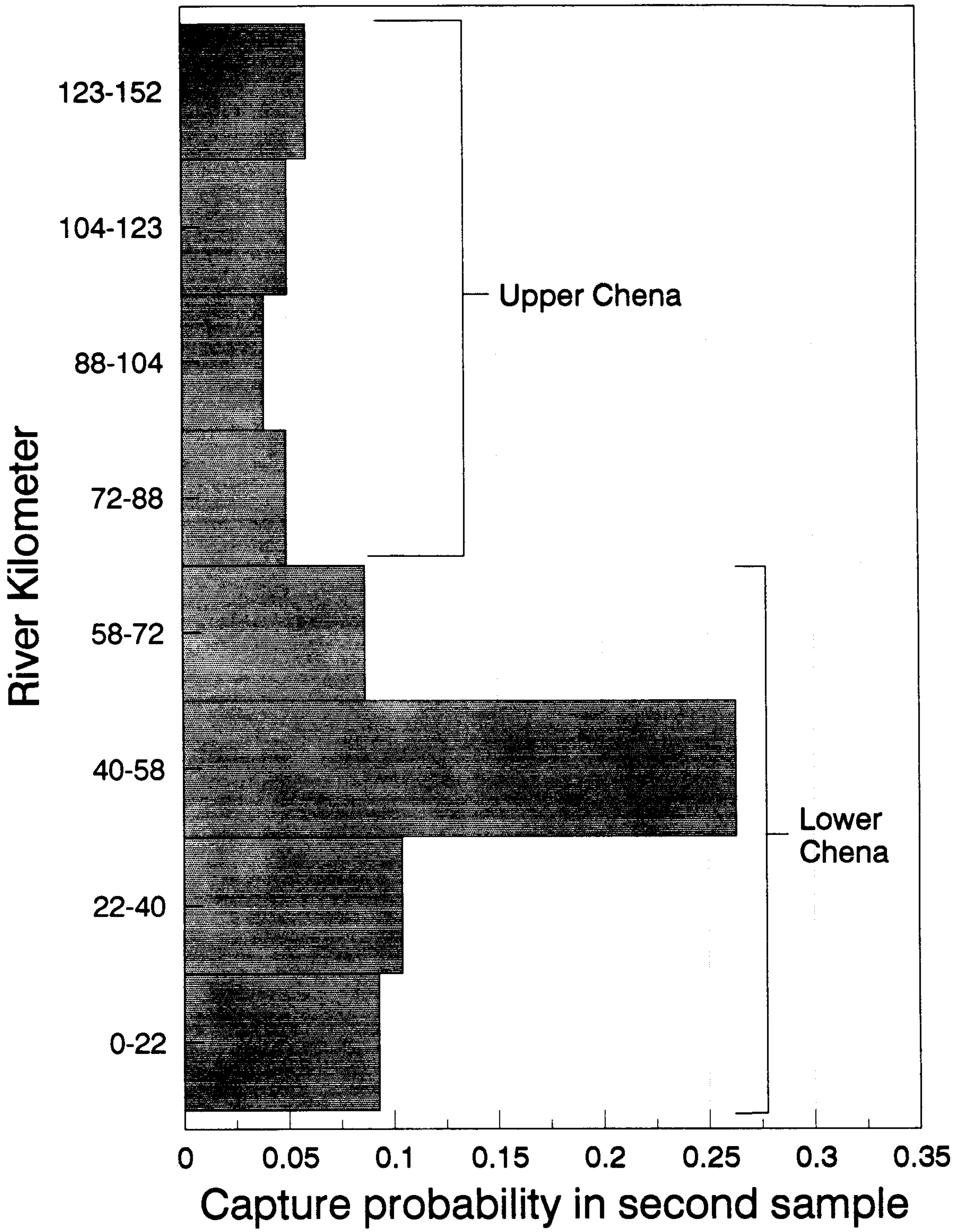

Figure 4. Recapture-to-catch ratios of wild Arctic grayling (≥ 150 mm FL) in eight reaches of the Chena River in 1993.

to mark Arctic grayling along both banks of the Lower (72 km long) and Upper Chena (80 km long) sections. Marking of fish in each section required four days, sampling four areas within a section. After a hiatus of seven days the two electrofishing boats were used in the same way to capture marked and unmarked Arctic grayling. The Lower Chena River experiment was conducted during the first two weeks of July and the Upper Chena experiment was conducted during the last two weeks of July.

The assumptions necessary for accurate estimation of abundance in a closed population are (from Seber 1982):

1) the population is closed (no change in the number of Arctic grayling in the population during the estimation experiment);

2) all Arctic grayling have the same probability of capture in the first sample <u>or</u> in the second sample, <u>or</u> marked and unmarked Arctic grayling mix completely between the first and second samples;

3) marking of Arctic grayling does not affect their probability of capture in the second sample;

4) Arctic grayling do not lose their mark between sampling events; and,

5) all marked Arctic grayling are reported when recovered in the second sample.

Testing of Assumptions:

Assumption 1 was implicitly assumed because of the large size of the sections (72 and 80 km) and short duration of the experiments (two weeks). A large section of river reduced the probability of fish leaving the section between sampling events. The short duration reduced the likelihood that mortality or recruitment due to growth would occur between sampling events. Assumptions 4 and 5 were assumed to be valid because of double marking of tagged Arctic grayling and rigorous examination of all captured Arctic grayling.

Assumptions 2 and 3 were tested directly in three ways. First, changes in capture probability may have occurred within a section of river. These potential changes were investigated by dividing each river section into four areas, each area encompassing the distance traveled during a single day of electrofishing. To determine if capture probability did change between areas, the recapture-to-catch ratios of each area were compared using a chi-squared contingency table. The four rows of the table were the different areas and the two columns of the table were the number of recaptures in the area and the number of unmarked fish examined during the second event in the same area. If the recapture-to-catch ratios were significantly different ($\alpha = 0.05$), the data were stratified into areas and separate abundance estimates calculated for each area.

Secondly, capture probability may differ by size of fish. Electrofishing is notorious for selecting for the largest fish in a population (Reynolds 1983), so that larger fish have a higher capture probability than smaller fish. Two Kolmogorov-Smirnov (K-S) statistical tests were used to determine if capture probability differs by size of fish. The first K-S test compared the length frequency distribution of recaptured Arctic grayling with those captured during the marking event. The second K-S test compared the length frequency distribution of Arctic grayling captured during the marking event with those captured in the recapture event (see Bernard and Hansen 1992 for a description of tests). The first K-S test was used to determine if capture probability varied by size of fish. If significantly different, the size at stratification was determined by performing a series of chi-squared tests at differing sizes (using two size strata). The size at stratification that produced the largest chi-squared value (the greatest difference in capture probability) was used to stratify the data for separate abundance estimation. The second K-S test was used to determine if age and size data needed to be corrected for changes in capture probability (see Estimation of Age and Size Composition below).

Lastly, capture probability may differ among wild and hatchery-reared fish. The method chosen to alleviate this potential bias was to separate the mark-recapture data for wild fish from hatchery-reared fish and perform the aforementioned tests on each group separately.

Calculation of Abundance:

After mark-recapture data were possibly stratified into areas and/or size classes with equal capture probabilities, estimated abundance was calculated from numbers of Arctic grayling marked, examined for marks, and recaptured (Bailey 1951; Seber 1982):

$$\hat{N}_i = \frac{n_1(n_2 + 1)}{m_2 + 1} \qquad (1)$$

where:

n_1 = the number of Arctic grayling marked and released alive during the first sample in stratum *i*;

n_2 = the number of Arctic grayling examined for marks during the second sample in stratum *i*;

m_2 = the number of Arctic grayling recaptured during the second sample in stratum *i*; and,

$\hat{N}_i$ = estimated abundance of Arctic grayling during the first sample in stratum *i*.

Variance was estimated by (Seber 1982):

$$\hat{V}\left[\hat{N}_i\right] = \frac{n_1^2(n_2 + 1)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)} \qquad (2)$$

Bailey's (1951, 1952) modification was used instead of the more familiar modification by Chapman (1951) because of the sampling design used on each river section. Seber (1982) found that if the assumption of a random sample for the second sample was false and a systematic sample was taken (for example, a systematic sample of both banks of the Chena River), then the binomial model of Bailey (1951, 1952) is most appropriate. The binomial model will hold in this situation when:

1) there is uniform mixing of marked and unmarked fish; and,

2) all fish, whether marked or unmarked, have the same probability of capture.

The sample design used in each river section does not allow for thorough mixing of fish marked at the uppermost reaches with those marked in the downstream reaches, although local mixing of marked and unmarked fish probably occurs.

Estimated abundance and variance of wild and hatchery fish in the lower 152 km of the Chena River was calculated as the sum of all strata (either areas, sizes, or both) from the Lower and Upper Chena sections:

$$\hat{N} = \sum_{i=1}^{s} \hat{N}_i \text{ , and} \qquad (3)$$

$$\hat{V}\left[\hat{N}\right] = \sum_{i=1}^{s} \hat{V}\left[\hat{N}_i\right]. \qquad (4)$$

where: s = the number of strata needed to alleviate bias due to changes in capture probability.

In 1993 there were eight strata for wild fish: three areas in the Lower Chena section, each containing two size strata, and two size strata in the Upper Chena section. There were two strata for hatchery-reared fish: hatchery releases in the Lower Chena section and hatchery releases in the Upper Chena section.

Estimation of Age and Size Composition

Collections of wild Arctic grayling for age-length samples were conducted in conjunction with abundance estimation experiments. Age composition was described with proportions of the stock contained in each age class from 2 through 12 years (third through thirteenth summers, respectively). Size composition of Arctic grayling in each of the river sections was described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and, "trophy" (greater than 559 mm FL). Incremental size composition was also estimated for each 10 mm increment of fork length from 150 mm to 450 mm. Incremental size composition was also used to describe the sizes of hatchery-reared fish sampled in the Chena River.

From tests of assumptions 2 and 3 for estimation of abundance, significant differences in capture probability by area and/or size of fish were found. Differences in capture probability may also bias estimates of age and size compositions. If significant changes in capture probability were detected, age and size data were adjusted for these differences so that the age and size composition of Arctic grayling in the lower 152 km of the Chena River could be estimated. First, the proportions of fish by age class or size category were estimated for each stratum used in estimation of abundance:

$$\hat{p}_{ik} = \frac{n_{ik}}{n_i} \tag{5}$$

where: $\hat{p}_{ik}$ = the proportion of age or size category *k* fish sampled in stratum *i*;

n_{ik} = the number of age or size category *k* fish sampled in stratum *i*; and,

n_i = the number of fish sampled in stratum *i*.

Variance of this proportion was estimated as the variance of a binomial. Next the abundance of each age class or size category was estimated from the proportions and abundance in each stratum:

$$\hat{N}_{ik} = \hat{p}_{ik}\hat{N}_i \tag{6}$$

where: $\hat{N}_{ik}$ = the abundance of age or size category *k* fish in stratum *i*.

Variance of each abundance at age or size was estimated with the formula for the variance of the product of two independent variables (Goodman 1960). After calculating abundances at age or size in each stratum, the overall proportions were estimated by:

$$\hat{\bar{p}}_k = \sum_{i=1}^{S} \frac{\hat{N}_i}{\hat{N}}\hat{p}_{ik} \tag{7}$$

where: $\hat{\bar{p}}_k$ = the average weighted proportion of Arctic grayling in the lower 152 km of the Chena River that were age or size *k*;

$\hat{N}_i$ = the abundance of Arctic grayling in stratum i;

$\hat{N}$ = summed abundance of all strata (from equation 3); and,

$\hat{p}_{ik}$ = the proportion of Arctic grayling in stratum *i* that were age or size *k*.

Variance of the proportions were approximated with the delta method (see Seber 1982):

$$\hat{V}\left[\hat{\bar{p}}_k\right] \approx \sum_{i=1}^{S} \frac{\left(\hat{p}_{ik} - \hat{\bar{p}}_k\right)^2 \hat{V}\left[\hat{N}_i\right]}{\hat{N}^2} + \sum_{i=1}^{S} \left(\frac{\hat{N}_i}{\hat{N}}\right)^2 \hat{V}\left[\hat{p}_{ik}\right] \tag{8}$$

These average weighted proportions and variances by age and size were used as estimates of age and size compositions in the lower 152 km of the Chena River.

Estimation of Proportion of Hatchery-Reared Fish

Mark-recapture data collected in each of the two river sections permitted separate estimation of abundance of age 1 hatchery-reared releases. No age 1 pond-reared releases were captured during sampling in 1993, so no estimate of abundance was calculated for this stocking cohort. The proportion of hatchery-reared fish in the lower 152 km of the Chena River was estimated as the quotient of the abundance of hatchery-reared fish and total abundance (wild plus enhancement):

$$\hat{p}_E = \frac{\hat{E}}{\hat{E} + \hat{W}} \tag{9}$$

where: $\hat{p}_E$ = proportion of the population that was from hatchery-reared releases in the lower 152 km of the Chena River;

$\hat{E}$ = abundance of hatchery-reared releases in the lower 152 km of the Chena River; and,

$\hat{W}$ = abundance of wild fish in the lower 152 km of the Chena River.

Variance of the proportion was approximated with the formula for the quotient of two dependent variables (Bernard 1983):

$$\hat{V}\left[\hat{p}_E\right] \approx \hat{p}_E^2 \left(\frac{\hat{V}\left[\hat{E}\right]}{\hat{E}^2} + \frac{\hat{V}\left[\hat{E}\right] + \hat{V}\left[\hat{W}\right]}{\left(\hat{E} + \hat{W}\right)^2} - \frac{2\hat{V}\left[\hat{E}\right]}{\hat{E}\left(\hat{E} + \hat{W}\right)} \right). \tag{10}$$

To examine changes in the proportion of hatchery-reared releases from downstream to upstream over the lower 152 km of the Chena River, catches of wild and hatchery-reared fish were recorded for each electrofishing run during the mark-recapture experiment. Capture probabilities of wild and hatchery-reared fish were compared with chi-squared contingency tables as detailed above (Testing of Assumptions). If capture probability of wild and hatchery-reared fish were similar for a particular area within a section, then the catches were used as an estimate of the proportion of hatchery-reared fish by electrofishing for that particular area. If capture probabilities differed for a particular area then the abundances of wild and enhancement fish in that area were used to adjust the proportions in each electrofishing pass (hereafter referred to as a run). First, it was assumed that capture probabilities of hatchery-reared fish were similar between all electrofishing runs within an area. This assumption applied to all wild fish in an area as well. The abundance of hatchery-reared fish in a particular electrofishing run was estimated by first estimating the proportion of the total catch of hatchery-reared fish in that area that were caught in that particular run:

$$\hat{p}_{E_{jm}} = \frac{e_{jm}}{e_j}, \text{ or } \hat{p}_{W_{jm}} = \frac{w_{jm}}{w_j} \tag{11}$$

where:

$\hat{p}_{E_{jm}}$ = the proportion of hatchery-reared fish caught in area *j* that were in electrofishing run *m*;

e_{jm} = the number of hatchery-reared fish caught in electrofishing run *m* of area *j*;

e_j = the number of hatchery-reared fish caught in area *j*;

$\hat{p}_{W_{jm}}$ = the proportion of wild fish caught in area *j* that were in electrofishing run *m*;

w_{jm} = the number of wild fish caught in area *j* that were in electrofishing run *m*; and,

w_j = the number of wild fish caught in area *j*.

Variances of equation 11 were estimated with the formula for the variance of a binomial. These proportions were also separately estimated for wild fish in each run.

Next, the abundances of hatchery-reared and wild fish were estimated for each run (showing the equation for hatchery-reared fish):

$$\hat{E}_{jm} = \hat{p}_{E_{jm}}\hat{E}_j \tag{12}$$

where:

$\hat{E}_{jm}$ = the abundance of hatchery-reared fish in run *m* of area *j* and,

$\hat{E}_j$ = the abundance of hatchery-reared fish in area *j*.

Variance of equation 12 was estimated with the formula for the variance of the product of two independent variables (Goodman 1960). The proportion of hatchery-reared fish in the run was then estimated by dividing the abundance of hatchery-reared fish in the run by the total abundance in the run:

$$\hat{p}'_{E_{jm}} = \frac{\hat{E}_{jm}}{\left(\hat{E}_{jm} + \hat{W}_{jm}\right)} \tag{13}$$

Variance of equation 13 was estimated with the approximate formula for the variance of the quotient of two dependent variables (as in equation 10, Bernard 1983). These calculations were performed in all areas where the recapture-to-catch ratios of wild and hatchery-reared fish were dissimilar. If recapture-to-catch ratios were similar, the catches of wild and hatchery-reared fish in each run were used to estimate the proportion of hatchery-reared fish in the run:

$$\hat{p}'_{Ejm} = \frac{e_{jm}}{\left(e_{jm} + w_{jm}\right)} \tag{14}$$

Variance of equation 14 was estimated with the formula for the variance of a binomial.

Estimation of Survival and Recruitment

As of 1993, eight years of population abundance and age composition estimates had been completed for the lower 152 km of the Chena River. Using data from 1986 through 1992, Clark (1993a) reported on survival rates and recruitment for 1986 through 1991. Survival rate and recruitment for 1992 was calculated in the same manner.

Annual recruitment was defined as the number of age 3 Arctic grayling added to the population between year *t* and year *t+1*, and alive in year *t+1*. Estimates of recruitment were simply the estimates of abundance of age 3 Arctic grayling in 1992 and 1993. Variance of the recruitment estimates were the variance of abundance at age 3 for these same years.

With recruitment and abundance at age estimates in years *t* and *t+1*, the estimate of survival rate between year *t* and year *t+1* was:

$$\hat{S}_{t,t+1} = \frac{\hat{N}'_{t+1}}{\hat{N}_t} \tag{15}$$

where: $\hat{N}'_{t+1} = \sum_{k=4}^{12} \hat{N}_{t+1,k}$

= the abundance of age *k* and older Arctic grayling in year *t*+1; and,

$\hat{N}_t = \sum_{k=3}^{12} \hat{N}_{t,k}$

= the abundance of age *k* and older Arctic grayling in year *t*.

The variance of annual survival was approximated as the variance of a quotient of two independent variables with the delta method (Seber 1982):

$$\hat{V}\left[\hat{S}\right] \approx \left[\frac{\hat{N}'_{t+1}}{\hat{N}_t}\right]^2 \left[\frac{\hat{V}\left[\hat{N}'_{t+1}\right]}{\hat{N}'^{2}_{t+1}} + \frac{\hat{V}\left[\hat{N}_t\right]}{\hat{N}^2_t}\right] \quad (16)$$

where: $\hat{V}\left[\hat{N}'_{t+1}\right] = \sum_{k=4}^{12} \hat{V}\left[\hat{N}'_{t+1,k}\right]$; and,

$$\hat{V}\left[\hat{N}_t\right] = \sum_{k=3}^{12} \hat{V}\left[\hat{N}_{t,k}\right].$$

Historic Data Summary

Data collected from the Chena River (1955 to 1993) were summarized in Appendix A. Creel survey estimates, population abundance estimates, length at age estimates, age composition estimates, size composition estimates, and a model of Arctic grayling growth were summarized from Federal Aid in Sport Fish Restoration reports and State of Alaska Fishery Data Series reports written from 1959 to the present (Appendix A). When possible, estimates of precision were reported with point estimates. Precision was reported as either standard error or 95% confidence interval. Sample sizes were reported if neither of these estimates of precision were available. Length frequency was generally reported in the literature as numbers sampled per 10 mm length increment. The length frequency distributions were converted into the RSD categories of Gabelhouse (1984) for comparison with data collected from 1986 to 1992. In addition to the aforementioned reports in Appendix A, Arctic grayling migration studies were summarized in a report by Tack (1980). Reports concerning Arctic grayling research from 1952-1980 were compiled by Armstrong (1982). Armstrong et al. (1986) have compiled a bibliography for the genus *Thymallus* to 1985. In addition, Clark (1992b) estimated age and size at maturity for the Chena River stock in 1991 and 1992, and Clark (1993b) estimated interannual intrastream movements of tagged fish for 1987 through 1992.

RESULTS

Hatchery-Reared Fish

Prior to release (13 May 1993) a sample of 306 hatchery-reared Arctic grayling were checked for the presence of an identifying fin clip (completely missing left ventral fin). Of these fish 299, or 97.7% of the sample (SE = 0.9%, normal approximation 95% C.I. = 96.0% to 99.4%), had an identifiable fin clip. Based on the percentage of identifiable fin clips in this sample, it was assumed that 97.7% of fish released into the Chena River had an identifiable fin clip. Average length of fish sampled was 198 mm FL (SE = 1 mm).

Between 1 and 11 June, 64,936 of the hatchery-reared fish were released at seven locations along the Chena River (Table 2). Average fork length of fish

Table 2. Releases of hatchery-reared Arctic grayling into the Chena River during 1 through 11 June 1993.

Date	River km	Number released	Average length[a]	Average weight[b]	River H_2O temp[c]	Tank H_2O temp[d]
6/1	22	7,700	209	87	11.0	8.0
6/2	14	6,658	218	100	11.5	9.0
6/3	40	6,537	214	102	ND	ND
6/7	72	10,031	214	102	9.0	10.5
6/8	72	10,031	214	102	10.5	10.5
6/9	117	6,534	214	102	8.5	10.0
6/10	>152[e]	7,414	208	90	9.5	12.0
6/11	104	10,031	208	90	9.0	11.0
Totals		64,936	212	97		

[a] Average length is in millimeter fork length.
[b] Average weight is in gram.
[c] River H_2O temp is the water temperature of the Chena River at the release location at the time of the release. ND indicates no temperature taken.
[d] Tank H_2O temp is the water temperature of the holding tanks used to transport the fish to the release site at the time of release. ND indicates no temperature taken.
[e] Exact river kilometer of release was not known. Release occurred just upstream of the second bridge crossing on the Chena Hot Springs Road.

at release varied from 208 mm to 218 mm by release location and averaged 212 mm overall. Average weight of fish at release varied from 87 g to 102 g by release location and averaged 97 g overall. River water temperature at the time of release ranged from 8.5°C to 11.5°C. Water temperature of the holding tanks at the time of release ranged from 8.0°C to 12.0°C.

Lower Chena River Section

The Lower Chena River experiment was performed during 6 through 15 July 1993. A total of 2,620 fish were marked, 1,939 fish were examined for marks, and 234 fish were recaptured during mark-recapture sampling. Twenty-nine immediate mortalities or serious injuries were recorded for an overall injury rate of 0.7%. Mark-recapture data from wild and hatchery-reared fish were analyzed separately.

Wild Fish:

A total of 1,225 wild fish were marked, 853 fish were examined for marks, and 116 were recaptured during mark-recapture sampling. Recapture-to-catch ratios of wild fish varied significantly among four areas of the Lower Chena (χ^2 = 35.50, df = 3, P ≈ 0.00; Figure 4). However, two adjacent areas of these four had similar recapture-to-catch ratios and were combined (χ^2 = 0.13, df = 1, P ≈ 0.72). There was no evidence of movement of marked fish between the four areas. Abundance, and age and size compositions were estimated separately in each of the resultant three areas. The three areas were: river kilometer 0 to 40; river kilometer 40 to 58; and, river kilometer 58 to 72 (see Table 3). Based on comparisons of length frequencies of marked fish with length frequencies of recaptured fish, there appeared to be size selective sampling in all three areas of the Lower Chena (Figure 5). However, there was a significant difference in length frequencies in river kilometer 0 to 40 alone (river kilometer 0-40: D = 0.24, P ≈ 0.01; river kilometer 40-58: D = 0.18, P ≈ 0.12; and, river kilometer 58-72: D = 0.33, P ≈ 0.13). The pattern of size selective sampling appeared similar in all areas so that data in all areas were stratified by length to correct for bias due to selectivity. The smallest recapture in river kilometer 40 to 58 and river kilometer 58 to 72 was 171 and 207 mm FL respectively. The smallest recapture in river kilometer 0 to 40 was 158 mm FL. Based on the need to estimate abundance for fish ≥ 150 mm FL in all areas and the demonstrated ability to recapture fish < 165 mm FL in one of the areas, the data were not truncated to 207 mm FL. Based on these observations and tests, experiments in all three areas were stratified into small (150 to 231 mm FL) and large fish (> 231 mm FL). Summing estimates of abundance from the six area/size strata (Table 3), estimated abundance of wild fish in the Lower Chena was 12,047 fish (SE = 1,685 fish).

There were no significant differences in the length frequencies of fish marked versus those examined for marks in any of the three areas used for abundance estimation (Figure 5). Results of K-S tests were: D = 0.04, P ≈ 0.84 for river kilometer 0 to 40; D = 0.09, P ≈ 0.27 for river kilometer 40 to 58; and,

Table 3. Capture probabilities and estimated abundance in three areas used for population estimation of wild Arctic grayling (≥ 150 mm FL) in the Lower Chena section of the Chena River, 6 through 15 July 1993.

River km	Mark n_1	Catch n_2	Recap m_2	m_2/n_1[a]	N[b]	SE[N][c]
<u>0 to 40</u>						
150-231 mm FL	407	260	15	0.04	6,638	1,560
≥ 232 mm FL	361	234	35	0.10	2,357	357
<u>40 to 58</u>						
150-231 mm FL	120	90	13	0.11	780	185
≥ 232 mm FL	183	108	39	0.21	499	62
<u>58 to 72</u>						
150-231 mm FL	66	62	3	0.05	1,040	450
≥ 232 mm FL	88	99	11	0.13	733	191
Total	1,225	853	116	0.09	12,047	1,685

[a] m_2/n_1 is the probability of capture for a length category.
[b] N is the estimated abundance in an area and/or length category.
[c] SE[N] is the standard error of N.

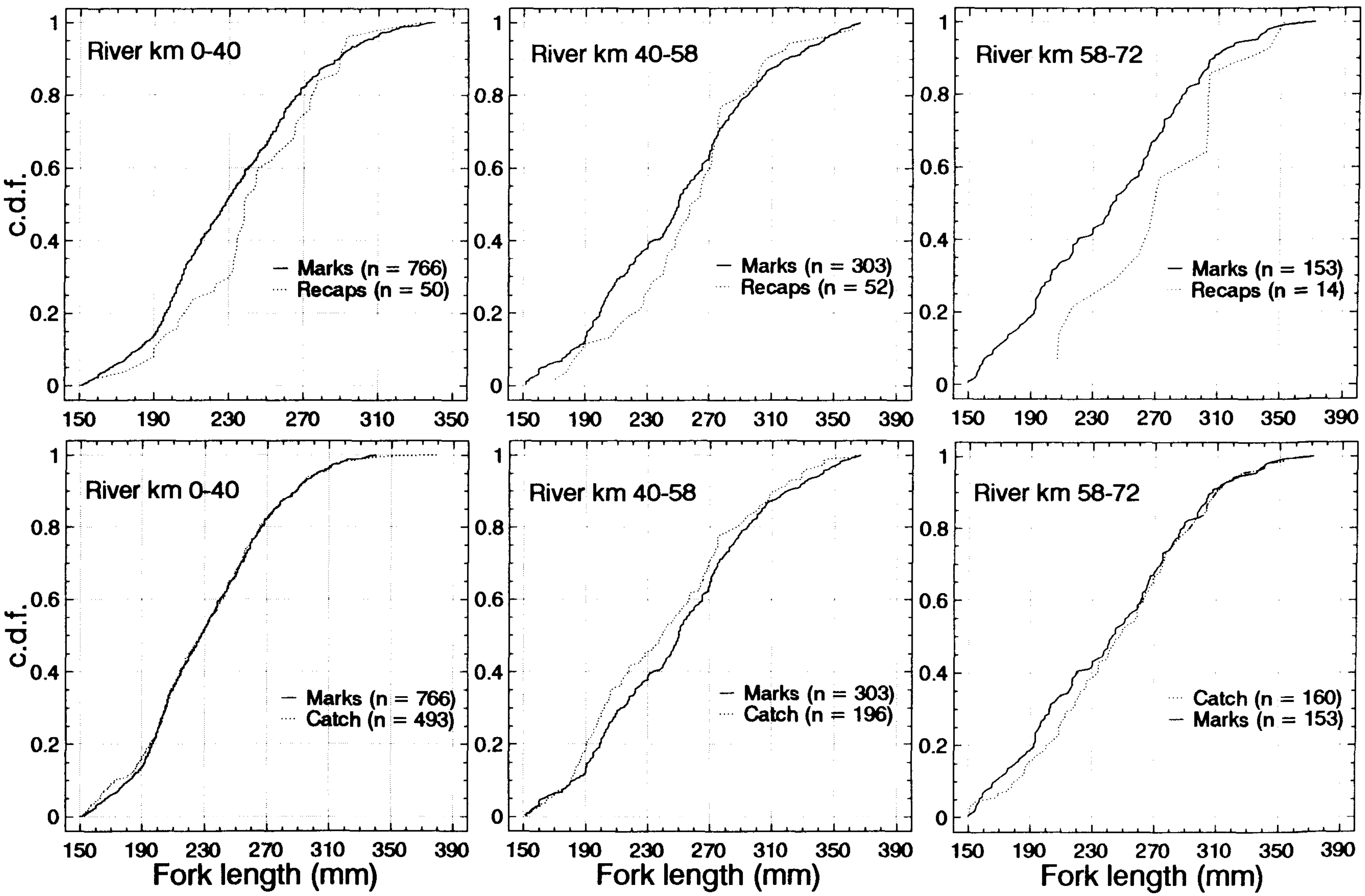

Figure 5. Cumulative density functions (c.d.f.) of fork length of wild Arctic grayling marked, captured, and recaptured in three areas of the Lower Chena section of the Chena River, 6 through 15 July 1993.

D = 0.11, P ≈ 0.33 for river kilometer 58 to 72. Therefore either sample (marking event or recapture event) could be used to estimate age and size composition. Ages were estimated from the recapture event, so that sizes were estimated from this event also. After combining estimates of age composition from each of the three areas in the Lower Chena section, age 3 fish were most abundant in this section of river (Table 4). Ages 2 through 4 comprised 82% of abundance, with very few fish older than age 8. Similarly, stock size fish comprised 87% of abundance in the Lower Chena while only 1% of fish were of preferred size (Table 5).

Hatchery-Reared Fish:

A total of 1,395 hatchery-reared fish were marked, 1,086 fish were examined for marks, and 118 were recaptured during mark-recapture sampling. Recapture-to-catch ratios did not significantly differ among four areas of the Lower Chena (χ^2 = 1.17, df = 3, P ≈ 0.76; Figure 6). There was a marginally significant difference in length frequencies of fish marked versus those recaptured (D = 0.13, P ≈ 0.06; Figure 7). The maximal chi-squared statistic occurred at a stratification of 150 to 211 mm FL for small fish and > 211 mm FL for large fish, but the stratified and summed estimate of abundance (13,107 fish, SE = 1,202 fish) was not different from the unstratified estimate of abundance (12,743 fish , SE = 1,098 fish). Stratification resulted in a 2.9% increase in abundance and a 6.4% increase in coefficient of variation (CV), so the unstratified estimate was used as the estimate of abundance of hatchery-reared fish in the Lower Chena.

There was no significant difference in length frequencies of fish marked versus those examined for marks (D = 0.04, P ≈ 0.19; Figure 7). Therefore either sample (marking event or recapture event) could be used to estimate age and size composition. Composition data were estimated from the recapture event for wild fish, so size composition and proportion of hatchery-reared fish by electrofishing run estimates were calculated from the recapture event. Based on abundances of wild and hatchery-reared fish, the proportion of hatchery-reared fish in the Lower Chena was 0.51 (SE = 0.04) or 51%.

<u>Upper Chena River Section</u>

The Upper Chena experiment was performed during 19 through 30 July 1993. A total of 2,092 fish were marked, 2,205 fish were examined for marks, and 105 fish were recaptured during mark-recapture sampling. Sixteen immediate mortalities or serious injuries were recorded for an overall injury rate of 0.4%. Mark-recapture data from wild and hatchery-reared fish were analyzed separately.

Wild Fish:

A total of 1,205 wild fish were marked, 1,221 fish were examined for marks, and 63 were recaptured during mark-recapture sampling. Recapture-to-catch ratios did not significantly differ among four areas of the Upper Chena (χ^2 =

Table 4. Estimates of adjusted age composition and abundance by age class with standard errors for wild Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Lower Chena section of the Chena River, 12 through 15 July 1993.

		Age Composition			Abundance		
Age	n[a]	p[b]	SE[c]	CV[d]	N[e]	SE[f]	CV[g]
2	85	0.17	0.02	12.0	2,047	376	18.4
3	258	0.47	0.03	7.2	5,720	897	15.7
4	155	0.18	0.02	10.9	2,179	386	17.7
5	107	0.09	0.01	17.4	1,050	233	22.2
6	59	0.05	0.01	20.3	563	138	24.5
7	22	0.02	<0.01	26.7	207	62	29.9
8	19	0.01	<0.01	28.1	167	52	31.1
9	10	0.01	<0.01	36.6	86	33	38.4
10	3	<0.01	<0.01	65.2	28	18	64.3
11	0	0	0	---	0	0	---
12	0	0	0	---	0	0	---
Total	718	1.000	---	---	12,047	1,685	14.0

[a] n = number of Arctic grayling sampled at age.
[b] p = estimated adjusted proportion of Arctic grayling at age in the population.
[c] SE = estimated standard error of p.
[d] CV = coefficient of variation of p, expressed as a percentage of p.
[e] N = estimated population abundance of Arctic grayling at age.
[f] SE = estimated standard error of N (Seber 1982).
[g] CV = coefficient of variation of N, expressed as a percentage of N.

Table 5. Summary of Relative Stock Density (RSD) indices of wild Arctic grayling (≥ 150 mm FL) captured in the Lower and Upper Chena sections, and the Chena River, 1993.

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
Lower Chena					
Number sampled	652	181	16	0	0
RSD	0.77	0.21	0.02	0.00	0.00
Adjusted RSD[b]	0.87	0.12	0.01	0.00	0.00
Standard Error	0.02	0.02	<0.01	0.00	0.00
Abundance	10,514	1,420	113	0	0
Standard Error	1,492	309	38	0	0
Upper Chena					
Number sampled	718	432	68	0	0
RSD	0.59	0.35	0.06	0.00	0.00
Adjusted RSD[b]	0.75	0.22	0.03	0.00	0.00
Standard Error	0.05	0.04	0.01	0.00	0.00
Abundance	20,694	5,942	935	0	0
Standard Error	3,627	1,464	253	0	0
Chena River					
Number sampled	1,370	613	84	0	0
RSD	0.66	0.30	0.04	0.00	0.00
Adjusted RSD[b]	0.79	0.19	0.02	0.00	0.00
Standard Error	0.03	0.03	<0.01	0.00	0.00
Abundance	31,208	7,362	1,048	0	0
Standard Error	4,028	1,449	246	0	0

[a] Minimum lengths for RSD categories are (Gabelhouse 1984): stock - 150 mm FL; quality - 270 mm FL; preferred - 340 mm FL; memorable - 450 mm FL; and, trophy - 560 mm FL.

[b] Adjusted RSD is the RSD corrected for differential vulnerability by length from electrofishing. Standard error of RSD is for the adjusted estimate.

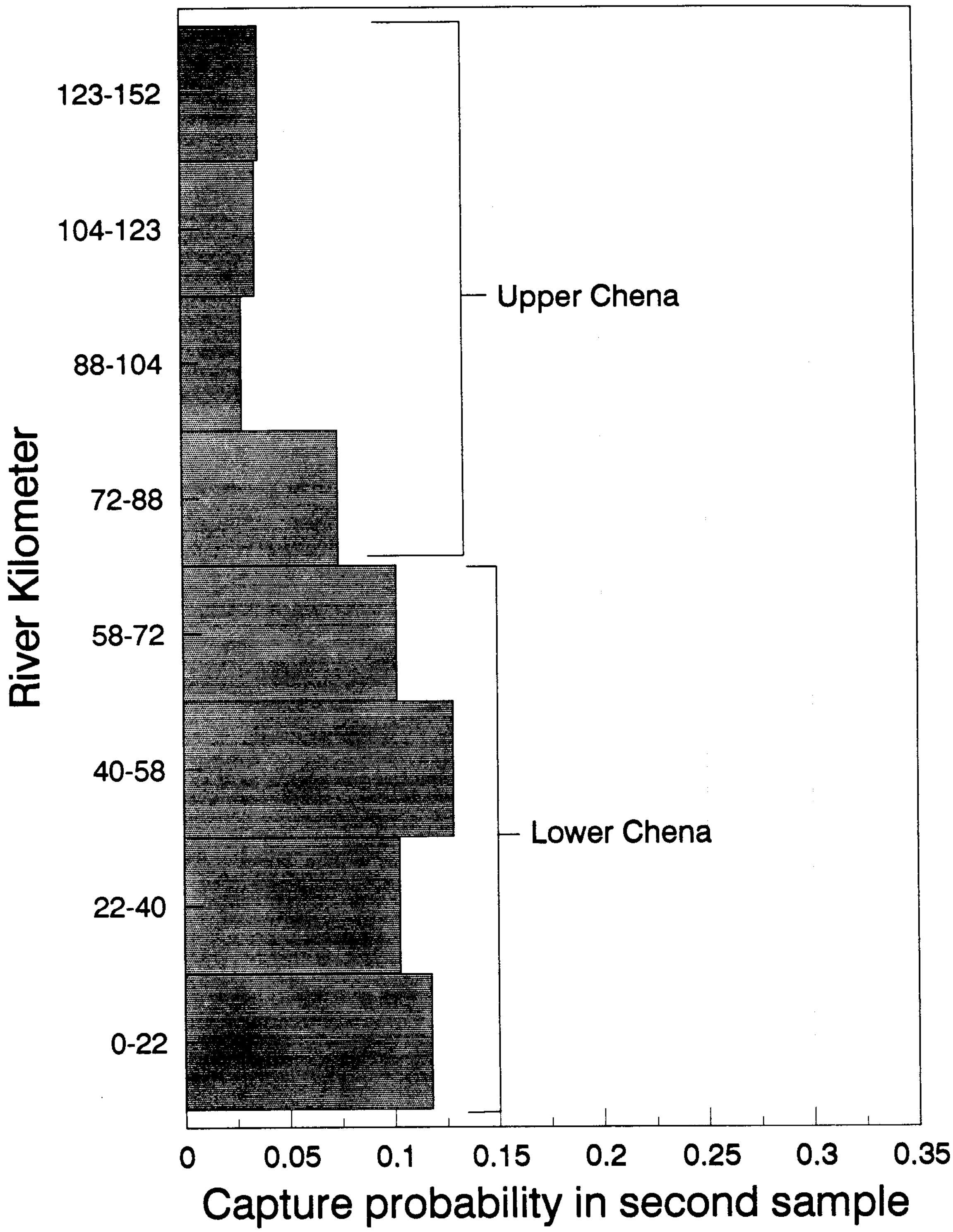

Figure 6. Recapture-to-catch ratios of hatchery-reared Arctic grayling (≥ 150 mm FL) in eight reaches of the Chena River in 1993.

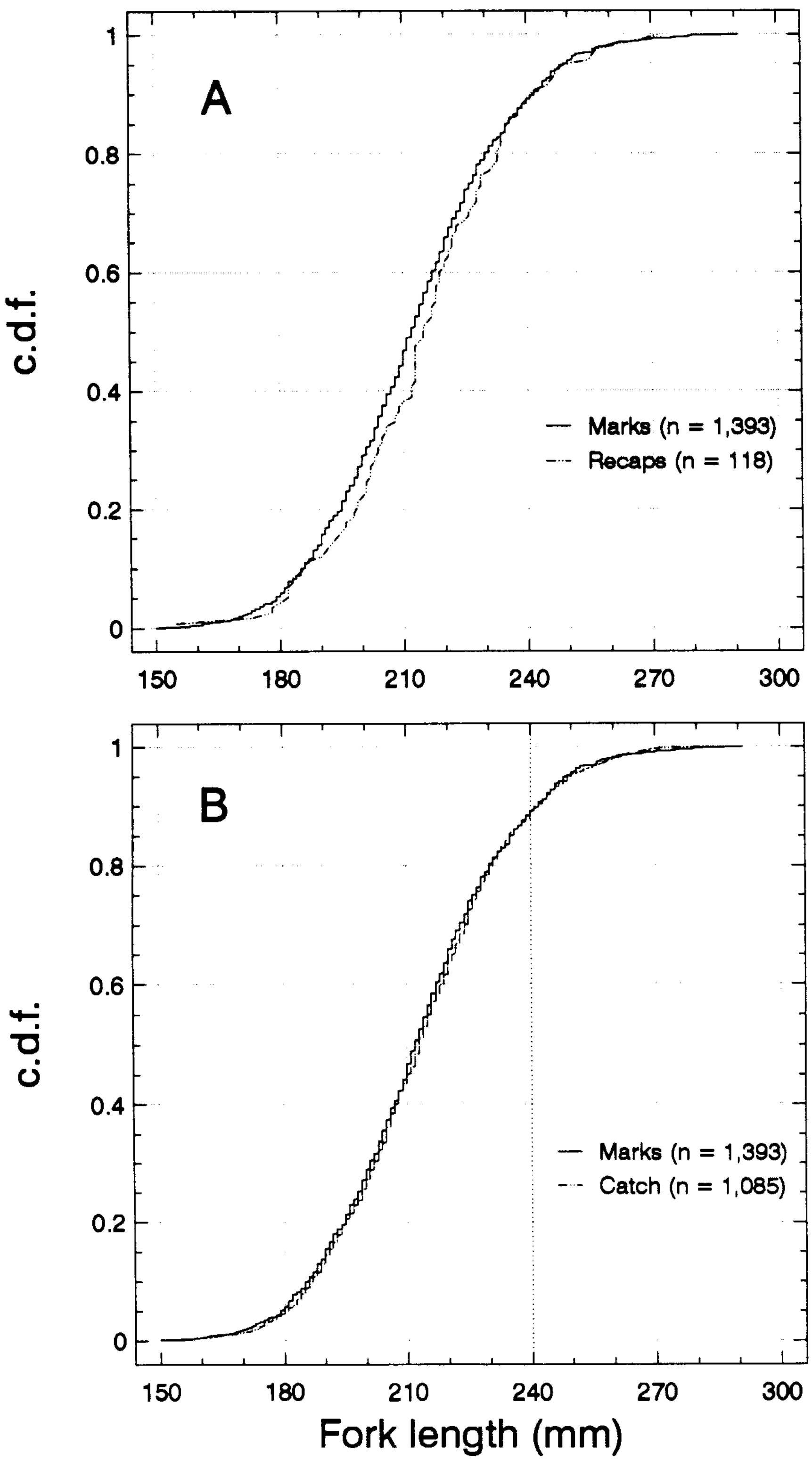

Figure 7. Cumulative density functions (c.d.f.) of fork length of hatchery-reared Arctic grayling marked, captured, and recaptured in the Lower Chena section of the Chena River, 6 through 15 July 1993.

1.39, df = 3, P ≈ 0.71; Figure 4). There was a significant difference in length frequencies of fish marked versus those recaptured (D = 0.20, P ≈ 0.01; Figure 8). The maximal chi-squared statistic occurred at a stratification of 150 to 248 mm FL for small fish and > 248 mm FL for large fish. The summed estimate of abundance of wild fish in the Upper Chena was 27,571 fish (SE = 4,533 fish; Table 6).

There was no significant difference in length frequencies of fish marked versus those examined for marks (D = 0.05, P ≈ 0.11; Figure 8). Therefore either sample (marking event or recapture event) could be used to estimate age and size composition. Ages were estimated from the recapture event, so that sizes were estimated from this event also. Age 3 fish were most abundant in this section of river (Table 7). Ages 2 through 6 comprised 92% of abundance, with very few fish older than age 9. Similarly, stock size fish comprised 75% of abundance in the Upper Chena while only 3% of fish were of preferred size (Table 5).

Hatchery-Reared Fish:

A total of 887 hatchery-reared fish were marked, 984 fish were examined for marks, and 42 were recaptured during mark-recapture sampling. Recapture-to-catch ratios did not significantly differ among four areas of the Upper Chena (χ^2 = 6.49, df = 3, P ≈ 0.09; Figure 6). There was no significant difference in length frequencies of fish marked versus those recaptured (D = 0.12, P ≈ 0.59; Figure 9). Although the smallest recapture was 189 mm FL, the need to estimate abundance of fish ≥ 150 mm FL in the Chena River and the demonstrated ability to recapture fish < 189 mm FL in the Lower Chena, required that the data not be truncated to 189 mm FL. The estimated abundance of hatchery-reared fish in the Upper Chena was 20,318 fish (SE = 2,995 fish).

There was no significant difference in length frequencies of fish marked versus those examined for marks (D = 0.04, P ≈ 0.55; Figure 9). Therefore either sample (marking event or recapture event) could be used to estimate age and size composition. Composition data were estimated from the recapture event for wild fish, so size composition and proportion of hatchery-reared fish by electrofishing run estimates were calculated from the recapture event. Based on abundances of wild and hatchery-reared fish, the proportion of hatchery-reared fish in the Upper Chena was 0.42 (SE = 0.05) or 42%.

<u>Chena River</u>

Summing estimated abundances from the Lower and Upper Chena sections, there was 39,618 wild fish (SE = 4,836 fish) and 33,061 hatchery-reared fish (SE = 3,190 fish) in the lower 152 km of the Chena River in July of 1993. The overall proportion of hatchery-reared fish was 0.46 (SE = 0.04) or 46%. Age 3 fish comprised 48% of the estimated abundance of wild fish, with age 2 fish accounting for 14% of abundance (Table 8). Seventy-nine percent of estimated abundance was of stock size fish, with only 2% of preferred size (Table 5). Abundance of age 3 and older fish was 34,209 fish (SE = 2,969 fish; Table 9).

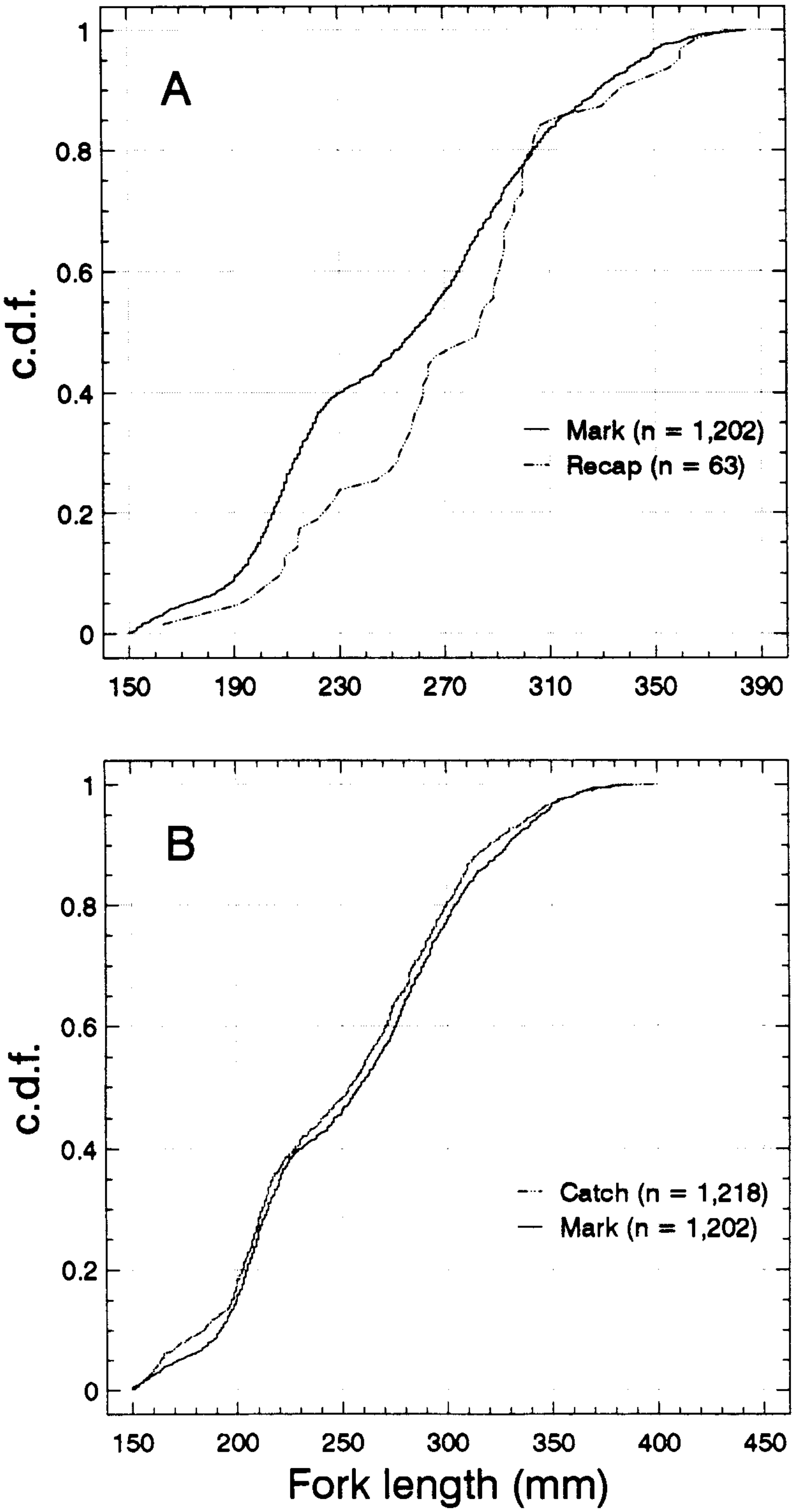

Figure 8. Cumulative density functions (c.d.f.) of fork length of wild Arctic grayling marked, captured, and recaptured in the Upper Chena section of the Chena River, 19 through 29 July 1993.

Table 6. Capture probabilities and estimated abundance in two size categories used for population estimation of wild Arctic grayling (≥ 150 mm FL) in the Upper Chena section of the Chena River, 19 through 29 July 1993.

Length category	Mark n_1	Catch n_2	Recap m_2	m_2/n_1[a]	N[b]	SE[N][c]
150 to 248 mm	548	583	16	0.03	18,825	4,372
≥ 249 mm	657	638	47	0.07	8,746	1,197
Total	1,205	1,221	63	0.05	27,571	4,533

[a] m_2/n_1 is the probability of capture.
[b] N is the estimated abundance in a length category.
[c] SE[N] is the standard error of N.

Table 7. Estimates of adjusted age composition and abundance by age class with standard errors for wild Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Upper Chena section of the Chena River, 26 through 29 July 1993.

		Age Composition			Abundance		
Age	n[a]	p[b]	SE[c]	CV[d]	N[e]	SE[f]	CV[g]
2	87	0.12	0.02	13.0	3,364	700	20.8
3	347	0.48	0.04	8.9	13,347	2,490	18.7
4	97	0.09	0.01	10.5	2,605	506	19.4
5	136	0.09	0.02	17.4	2,470	587	23.8
6	223	0.14	0.02	17.9	3,910	944	24.1
7	36	0.02	0.01	24.2	615	178	29.0
8	36	0.02	0.01	24.2	615	178	29.0
9	22	0.01	<0.01	27.9	375	120	32.1
10	10	0.01	<0.01	35.5	171	66	38.7
11	4	<0.01	<0.01	52.0	69	37	53.9
12	2	<0.01	<0.01	75.0	33	25	75.8
Total	1,000	1.000	---	---	27,571	4,533	16.4

[a] n = number of Arctic grayling sampled at age.
[b] p = estimated adjusted proportion of Arctic grayling at age in the population.
[c] SE = estimated standard error of p.
[d] CV = coefficient of variation of p, expressed as a percentage of p.
[e] N = estimated population abundance of Arctic grayling at age.
[f] SE = estimated standard error of N (Seber 1982).
[g] CV = coefficient of variation of N, expressed as a percentage of N.

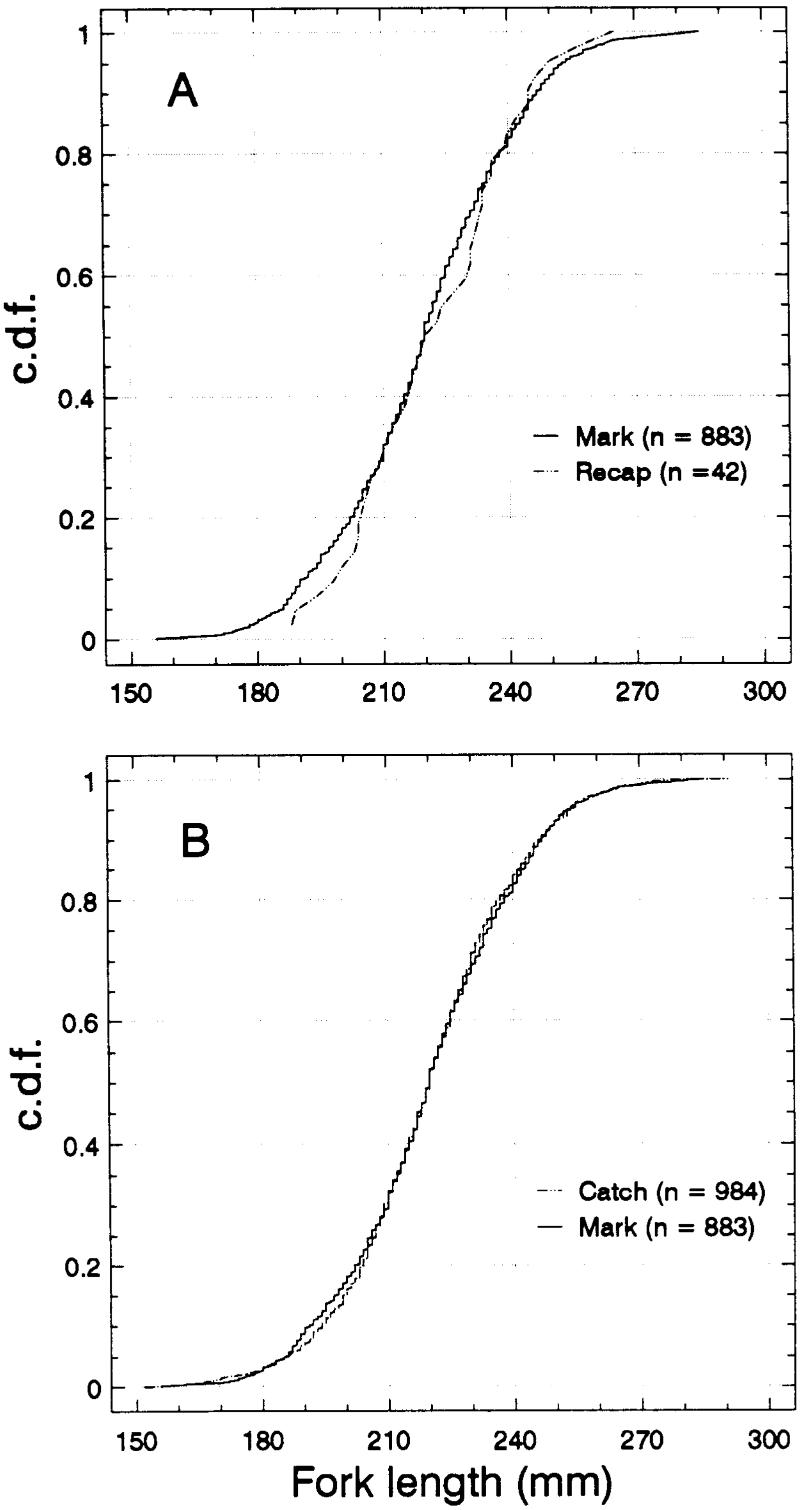

Figure 9. Cumulative density functions (c.d.f.) of fork length of hatchery-reared Arctic grayling marked, captured, and recaptured in the Upper Chena section of the Chena River, 19 through 29 July 1993.

Table 8. Estimates of age composition and abundance by age with standard errors for wild Arctic grayling captured by pulsed-DC electrofishing from the Lower and Upper Chena sections and the Chena River, 1993.

	Lower Chena[a]				Upper Chena[b]				Chena River[c]			
Age	p[d]	SE[e]	N[f]	SE[g]	p	SE	N	SE	p	SE	N	SE
2	0.17	0.02	2,047	376	0.12	0.02	3,364	700	0.14	0.01	5,410	795
3	0.47	0.03	5,719	897	0.48	0.04	13,347	2,490	0.48	0.03	19,066	2,647
4	0.18	0.02	2,179	386	0.09	0.01	2,605	506	0.12	0.01	4,785	636
5	0.09	0.01	1,050	233	0.09	0.02	2,470	587	0.09	0.01	3,521	632
6	0.05	0.01	563	138	0.14	0.02	3,910	944	0.11	0.02	4,472	954
7	0.02	0.01	207	62	0.02	0.01	615	178	0.02	<0.01	822	189
8	0.01	<0.01	167	52	0.02	0.01	615	178	0.02	<0.01	782	186
9	0.01	<0.01	86	33	0.01	<0.01	375	120	0.01	<0.01	460	125
10	<0.01	<0.01	28	18	0.01	<0.01	171	66	0.01	<0.01	199	69
11	0	0	0	0	<0.01	<0.01	69	37	<0.01	<0.01	69	37
12	0	0	0	0	<0.01	<0.01	33	25	<0.01	<0.01	33	25
Totals	1.000	---	12,047	1,685	1.00	---	27,571	4,533	1.00	---	39,618	4,836

[a] Lower Chena section - River kilometer 0 to 72.0.
[b] Upper Chena section - River kilometer 72.0 to 152.0.
[c] Chena River - River kilometer 0 to 152.0.
[d] p = estimated proportion of Arctic grayling at age in the section.
[e] SE = estimated standard error of p.
[f] N = estimated population abundance of Arctic grayling at age in the section.
[g] SE = estimated standard error of N.

Table 9. Summary of population abundance, annual survival (%), annual recruitment, and standard error estimates during 1986-1993 for wild Arctic grayling (≥ age 3) in the lower 152 km of the Chena River.

Year	Abundance	SE	Survival %	SE	Recruitment	SE
1986[a]	61,581	26,987				
			43.9	20.1	2,526	358
1987[a]	29,580	3,525				
			57.1	8.1	3,373	529
1988[a]	20,268	1,214				
			58.7	9.0	4,332	491
1989[a]	16,236	1,618				
			75.4	11.0	16,881	4,172
1990[a]	29,130	4,373				
			74.7	13.2	2,882	368
1991[a]	24,657	2,082				
			78.8	8.2	5,773	591
1992[a]	25,211	1,333				
			60.1	6.2	19,066	2,647
1993	34,209	2,969				

[a] Source document for parameter estimates in these years is Clark (1993).

Survival rate of age 3 and older fish from 1992 to 1993 was 0.60 (SE = 0.06; Table 9). Recruitment from 1992 to 1993 (age 3 fish) was 19,066 fish (SE = 2,647 fish). Data files used to estimate abundance, and age and size compositions are listed in Appendix B1.

During stock assessment in July, hatchery-reared fish were found in all electrofishing runs (Figure 10). Highest estimated abundance of fish occurred between river kilometer 115 and 119, with additional peaks in estimated abundance at river kilometer 32 and 70. The proportion of hatchery-reared fish in the Chena River also varied greatly among electrofishing runs (Figure 11). Although the overall proportion of hatchery-reared fish was 0.46, estimates ranged from 0.10 (SE = 0.03) at river kilometer 136 to 0.90 (SE = 0.04) at river kilometer 70 (Figure 11). Estimated survival of hatchery-reared fish from time of release to time of stock assessment was 0.51 (SE = 0.05). Average length of hatchery-reared fish during stock assessment was 217 mm FL (SD = 21 mm FL, SE = 1 mm FL). Size composition of hatchery fish was similar to the length range of maximum abundance of wild fish (Figure 12).

DISCUSSION

Sample Design

The sampling design used during the past three years has provided estimates of abundance of wild fish that are sufficiently precise for management (CV < 13%). In 1993 CV of the abundance estimate for wild fish was 12.2%. This sampling design also allowed for precise estimation of abundance of hatchery-reared fish as well (CV = 9.6%). The original sampling design prescribed a sampling intensity that would allow estimation of abundance of hatchery-reared fish from estimates of the proportion of hatchery-reared in catch samples multiplied by estimates of total (hatchery plus wild) abundance. In actuality, sampling intensity was sufficient to estimate abundance of wild and hatchery-reared fish independently. This method avoided problems with differential capture probability among groups that could have biased estimates of the proportion of hatchery-reared fish within an electrofishing run or within an area of river. However, an additional 60,000 hatchery-reared fish are scheduled to be released into the Chena River in June 1994. If projected abundance of wild fish in 1994 is similar to 1993 and survival from release to stock assessment of the 1994 release is similar to 1993, then total abundance may be sufficiently high to prevent handling and marking of every fish captured during stock assessment. Insufficient recaptures of any group of fish (wild, age 2 hatchery, or age 1 hatchery fish) may complicate the precise estimation of abundance for one or more of these groups. Plans for sampling in 1994 should attempt to address this potential problem. Sampling in 1994 will focus on estimation of abundance of age 2 hatchery-reared fish and estimation of survival (from time of release to July 1994 and from July 1993 to July 1994) of this cohort.

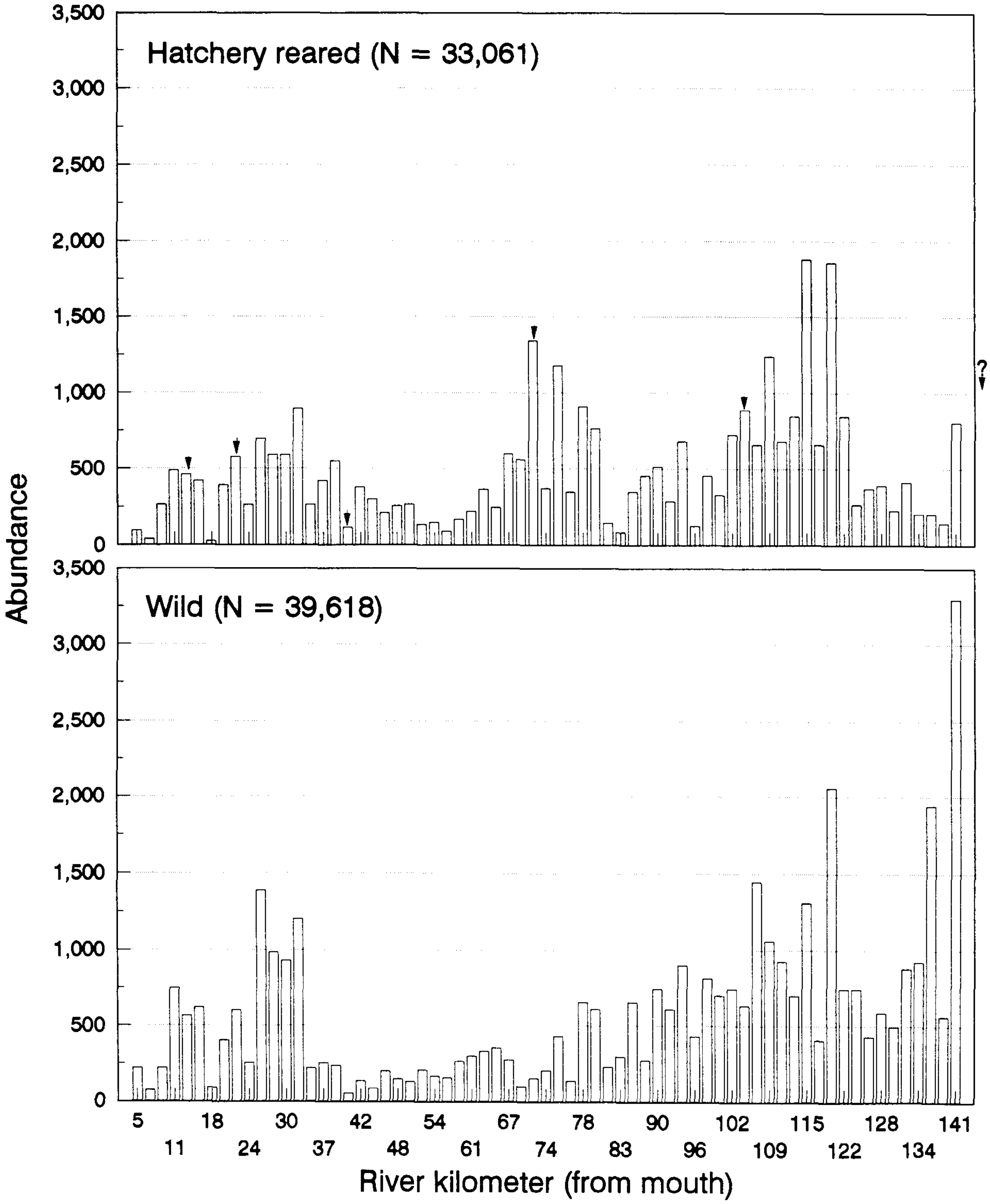

Figure 10. Estimated abundance of hatchery-reared and wild Arctic grayling by river kilometer of the Chena River during 6 through 29 July 1993. Arrows denote release locations.

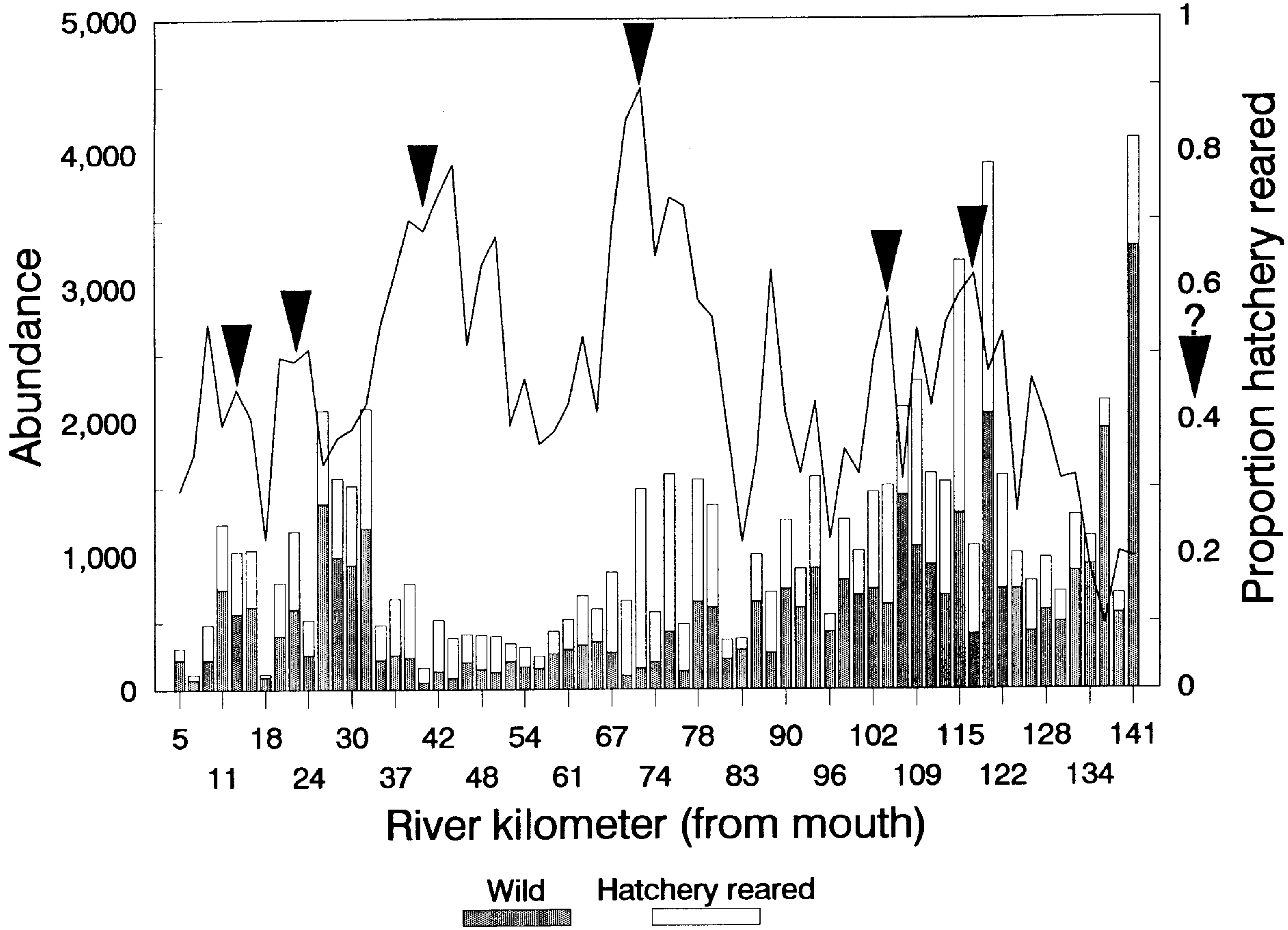

Figure 11. Estimated abundance of wild and hatchery-reared Arctic grayling and proportion of hatchery-reared Arctic grayling (≥ 150 mm FL) by river kilometer of the Chena River during 6 through 29 July 1993. Arrows denote release locations.

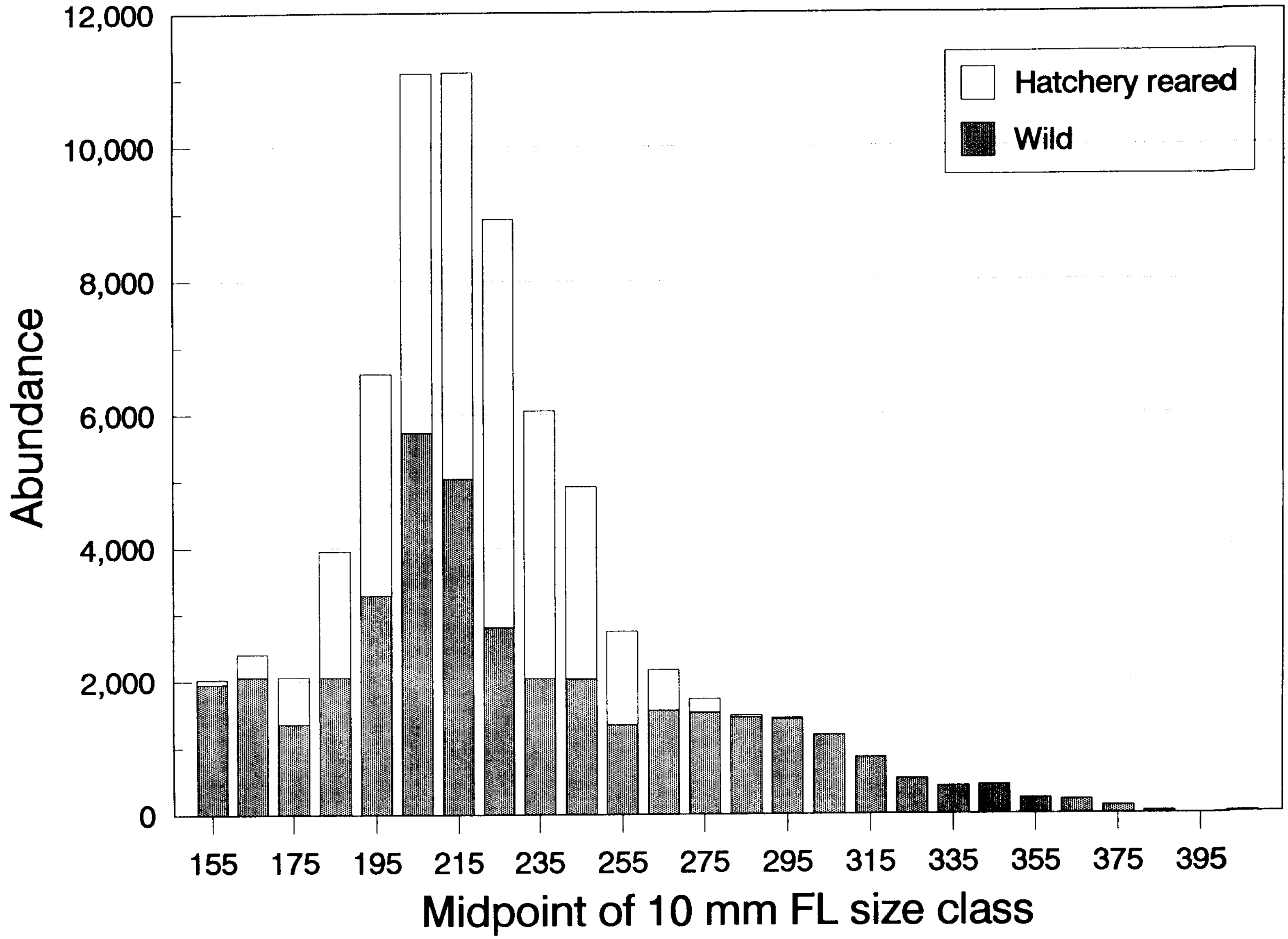

Figure 12. Estimated abundance of wild and hatchery-reared Arctic grayling by 10 mm fork length increment in the Chena River during 6 through 29 July 1993.

Stock Status

The stock of wild fish in the Chena River experienced the strongest recruitment since 1986. From the relation between natal year stream flows and survival to recruitment, recruitment was predicted to be above average in 1993 (Clark 1992a). However, the model also predicts below average recruitment for 1994 and 1995, with average to above average recruitment in 1996. Alternatively, the 1993 estimate of prerecruits (age 2 fish) is much higher than would be expected for the below average recruitment anticipated for 1994. Since summer feeding conditions were good (low, warm water conditions) prior to stock assessment in 1993, prerecruits may have experienced above average growth prior to stock assessment in 1993. This may have allowed more age 2 fish into the defined population (≥ 150 mm FL) in 1993 than might have been seen in past years of stock assessment.

Annual survival for 1992 through 1993 was the lowest since the period between 1988 and 1989. Harvest of Arctic grayling in the recreational fishery was prohibited by regulation for 1992 and 1993, so that the estimate of survival can be considered an estimate of natural survival. Between 1991 and 1992, natural survival was 78.8% and between 1992 and 1993 natural survival was 60.1%. Although the estimate for 1992 through 1993 is lower than for the previous year, these two estimates are well within the range of estimates observed for Arctic grayling in Fielding Lake during 1986 through 1991 (Clark in prep.) and in the Chena River prior to 1992 (unpublished data).

Hatchery-Reared Fish

From the time of release in June 1993 and time of stock assessment in July 1993, hatchery-reared fish experienced a reduction in abundance from 64,936 fish to 33,061 fish. This reduction is higher than might be expected, given the short period of time (between 4 and 6 weeks) at large. Conditions during release appeared to be optimal, with low stream flows and water temperatures near that of the rearing facility at Clear Hatchery (~13°C). Few immediate mortalities were noted during release, although disorientation of fish was evident for approximately the first 1 hour after release. However, the estimate of abundance of hatchery-reared fish in July should be considered a minimum. One release (7,414 fish) was made approximately 10 river kilometers upstream of the area of stock assessment. Although some of these fish may have moved downstream into the area and contributed to the documented abundance estimate, it is unlikely all survivors from this release were inside the area. Moreover, anecdotal evidence suggests that some hatchery-reared fish moved into tributaries of the mainstem Chena River. One hatchery-reared fish was identified from a sample of approximately 400 fish taken from the East Fork of the Chena River (Nicholas Hughes, Simon Fraser University, personal communication). One hatchery-reared fish was identified from a sample (unknown number of fish) taken from the Little Chena River (Allen Townsend, Alaska Department of Fish and Game, personal communication). One angler commented that several hatchery-reared fish (denoted as "missing a belly clip") were seen in Badger Slough.

Evidence of movement of hatchery-reared fish after release was documented inside the area of assessment as well. Although fish were not marked to identify release location, it appears from estimates of abundance and proportion of hatchery-reared fish by electrofishing run that these fish rapidly moved upstream and downstream of the release locations. From these estimates it appears that the decision to utilize release locations along the entire length of the area where stock assessment is performed resulted in a more uniform distribution of fish along the river than is seen in the natural distribution of wild fish in the same area. A similar range of release locations is anticipated for 1994.

There were some unusual characteristics of hatchery-reared fish that should also be noted. A high proportion (not estimated) of male hatchery-reared fish appeared to extrude a substance similar to milt when handled during stock assessment. Although none of this substance was collected for confirmation, perhaps the rapid growth experienced in hatchery rearing caused premature formation of active gonads. In addition, all hatchery-reared fish were sufficiently different in external coloration from wild fish as to render the identifying fin clip unnecessary. Hatchery-reared fish were silver/gray in color while wild fish are tan, brown, or dark-gray in color. Moreover, no hatchery-reared fish had the black spot pattern typical of wild fish of the same length. Lack of spots in hatchery-reared fish may be a consequence of their age (1 year). Wild Arctic grayling do not develop permanent black spots along their flanks until the age of 3 or 4 years, although juvenile spots (these fade with age) are present at age 1. Additionally, a high proportion of hatchery-reared fish exhibited poor condition (large head relative to body size). Future research on these fish should include estimation of sexual maturity schedule (by size and age), growth, annual survival, and interannual movements.

ACKNOWLEDGMENTS

The author extends thanks to William Ridder, Douglas Fleming, Stafford Roach, Mark D. Ross, William Leslie, John Burr, Jerry Hallberg, Fred Andersen, Margaret Merritt, and Doug Edwards for their expertise in the field. David Parks, Don Bee, and Tim Burke of the Division of Commercial Fisheries Management and Development at Clear Hatchery are to be thanked for performing the egg take, rearing of fish at the hatchery, and release of fish into the Chena River. Alyeska Pipeline Company is commended for providing access to a pond for holding prespawning fish. Thanks also go to the biometric support staff, namely David Bernard and Allen Bingham, for aiding in the development of statistical procedures used in this report. John H. Clark, Fred Andersen, and Margaret Merritt are commended for their supervisory, coordination, and editorial roles that provided the structure necessary for implementing this project. Allen Bingham is also commended for his editorial assistance. Thanks also go to Sara Case for editing and printing of this report. This project and report were made possible by partial funding provided by the U.S.

Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under project F-10-9, Job Number R-3-2(a).

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APPENDIX A
Historic Data Summary

Appendix A1. Source citations for Federal Aid and Fishery Data Reports used for data summaries, 1955-1958 and 1967-1993.

Year	Type of Data[a]	Source Document
1955	CC	Warner (1959)
1956	CC	Warner (1959)
1957	CC	Warner (1959)
1958	CC	Warner (1959)
1967	AL, CC, POP	Van Hulle (1968)
1968	AL, CC, POP	Roguski and Winslow (1969)
1969	AL, CC, POP	Roguski and Tack (1970)
1970	CC, POP	Tack (1971)
1971	POP	Tack (1972)
1972	CC, POP	Tack (1973)
1973	AL, POP	Tack (1974)
1974	AL, CC, POP	Tack (1975)
1975	AL, CC, POP	Tack (1976)
1976	AL, CC, POP	Hallberg (1977)
1977	AL, CC, POP	Hallberg (1978)
1978	AL, CC, POP	Hallberg (1979)
1979	AL, CC, POP	Hallberg (1980)
1980	AL, CC, POP	Hallberg (1981)
1981	AL, CC, POP	Hallberg (1982)
1982	AL, CC, POP	Holmes (1983)
1983	AL, CC, POP	Holmes (1984)
1984	AL, CC, POP	Holmes (1985)
1985	AL, CC, POP	Holmes et al. (1986)
1986	CC	Clark and Ridder (1987a)
	AL, POP	Clark and Ridder (1987b)
1987	CC	Baker (1988)
	AL, POP	Clark and Ridder (1988)
1988	CC	Baker (1989)
	AL, POP	Clark (1989)
1989	CC	Merritt et al. (1990)
	AL, POP	Clark (1990)
1990	AL, POP	Clark (1991)
1991	AL, POP	Clark (this report)
	CC	Hallberg and Bingham (1992)
1992	AL, POP	Clark (1993a)
1993	AL, POP	Clark (this report)

[a] CC = Creel census estimates;
AL = age and size composition estimates; and,
POP = population abundance estimates.

Appendix A2. Chena River study sections used from 1968 to 1985[a].

Section Number	Section Name	River Kilometers	Length in Kilometers
1	River mouth to University Ave.	0-9.6	9.6
2A	University Ave. to Peger Road	9.6-12.8	3.2
2B	Peger Road to Wendell Street	12.8-17.6	4.8
3	Wendell St. to Wainwright Bridge	17.6-23.2	5.6
4	Wainwright Bridge to Badger Slough	23.2-34.4	11.2
5	Badger Slough		26.4
6	Badger Slough to Little Chena R.	34.4-39.2	4.8
7	Little Chena River		98.4
8	Little Chena to Nordale Slough	39.2-49.6	10.4
DS	Nordale Slough to Bluffs	49.6-88.8	39.2
9B	Bluffs to Bailey Bridge	88.8-100.8	12.0
10	Bailey Bridge to Hodgins Slough	100.8-126.4	25.6
11	Hodgins Slough to 90 Mi. Slough	126.4-144.0	17.6
12	90 Mi. Slough to First Bridge	144.0-147.2	3.2
13	First Bridge to Second Bridge	147.2-151.2	4.0
14	Second Bridge to North Fork	151.2-163.2	12.0
15	North Fork of Chena River		56.0
16	East Fork of Chena River		99.2
17	West Fork of Chena River		56.0

[a] Taken from Hallberg 1980.

Appendix A3. Summary of population abundance estimates of Arctic grayling ($\geq$ 150 mm FL) in the Chena River, 1968-1993.

Year	Dates	Area[a]	Estimator[b]	Estimate	Confidence[c]
1968	Summer?	2	SN	411/km	393-1,209
	Summer?	6	SN	283/km	228-381
1969	June?	2	SN	596/km	474-850
	June?	6	SN	571/km	439-816
1970	7/02-7/10	2	SN	919/km	690-1,519
	5/26-5/30	6	SN	373/km	346-408
	6/08-7/08	9B	SN	1,005/km	803-1,411
	6/07-7/07	10	SN	1,171/km	876-1,957
1971	8/30-9/03	2A	SN	300/km	192-1,157
	6/02-6/07	2B	SN	1,302/km	958-2,305
	8/30-9/03	2B	SN	2,338/km	1,753-3,897
	6/21-6/24	6	SN	189/km	161-233
1972	6/22-6/26	2A	SN	309/km	236-489
	6/22-6/26	2B	SN	608/km	493-828
	6/19-6/20	6	SN	159/km	124-235
	6/27-6/29	DS	SN	812/km	604-1,393
1973	7/10-7/13	2A	SN	293/km	218-502
	7/03-7/14	2B	SN	424/km	354-545
	7/16-7/17	6	SN	243/km	203-312
	7/18-7/19	DS	SN	500/km	379-806
1974	6/26-6/28	2A	SE	65/km	36-372
	6/25-6/28	2B	SE	488/km	207-1,378
	8/13-8/15	6	SE	100/km	71-164
	7/09-7/11	DS	SE	263/km	221-326
1975	7/10-7/14	6	SE	191/km	114-589
1976	7/19-7/21	2A	SE	258/km	223-307
	7/22-7/24	2B	SE	409/km	323-556
	7/28-7/30	6	SE	163/km	153-175
	8/04-8/06	DS	SE	306/km	285-329
1977	7/05-7/08	2A	SE	318/km	298-343
	7/11-7/14	2B	SE	318/km	280-370
	7/18-7/21	6	SE	173/km	170-177
	7/26-7/30	DS	SE	315/km	283-359
1978	7/14-7/17	2A	SE	69/km	44-156
	7/25-7/28	2B	SE	162/km	148-179
	7/10-7/13	6	SE	226/km	210-243
	8/08-8/11	DS	SE	345/km	333-359

-continued-

Appendix A3. (Page 2 of 2).

Year	Dates	Area[a]	Estimator[b]	Estimate	Confidence[c]
1979	7/01-7/03	2A	SE	57/km	45-76
	6/26-6/30	2B	SE	201/km	188-216
	8/20-8/23	8A	SE	177/km	161-197
	7/17-7/20	DS	SE	193/km	144-288
1980	7/01-7/04	2B	SE	308/km	229-471
	7/14-7/17	8A	SE	190/km	154-248
	7/29-8/01	DS	SE	236/km	200-287
	8/12-8/15	10B	SE	842/km	640-1,234
1981	8/07-8/10	2B	SN	262/km	223-392
	8/03-8/06	8A	SN	224/km	164-309
	8/11-8/14	DS	SN	302/km	174-440
	7/21-7/24	10B	SN	869/km	466-1,778
1982	7/16-7/20	2B	SN	116/km	79-177
	7/13-7/15	8A	SN	87/km	60-132
	7/23-7/27	DS	SN	232/km	113-579
	7/28-7/30	10B	SN	875/km	529-1563
1983	7/13-7/15	2B	SN	216/km	168-265
	7/05-7/07	8A	SN	119/km	81-545
	7/8,7/11-7/12	DS	SN	209/km	149-303
	7/26-7/28	10B	SN	911/km	647-1,338
	7/19-7/21	12	SN	208/km	138-332
1984	7/16-7/18	2B	SN	211/km	167-268
	7/3,7/05-7/06	8A	SN	139/km	95-215
	7/09-7/11	DS	SN	179/km	124-273
	7/19-7/20	10B	P	493/km	275-1,003
	7/31,8/02-8/03	12	SN	1,318/km	449-6,592
1985	7/10-7/17	2B	SN	189/km	92-287
	6/26-7/02	8A	SN	271/km	189-360
	7/03-7/08	DS	SN	333/km	234-432
	7/22-7/31	10B	SN	1,156/km	304-3,035
	6/12-6/24	12	SN	1,092/km	552-1,643
1986	7/07-8/06	WC	EXP	61,581	SE = 26,987
1987	6/27-7/30	WC	EXP+P	31,502	SE = 3,500
1988	6/26-8/04	WC	EXP+P	22,204	SE = 2,092
1989	7/10-8/03	WC	EXP+P	19,028	SE = 1,578
1990	7/02-8/03	WC	EXP+P	31,815	SE = 4,880
1991	7/08-8/01	WC	P	26,756	SE = 3,286
1992	7/06-7/30	WC	P	29,349	SE = 2,341
1993	7/06-7/29	WC	P	39,618	SE = 4,836

[a] Areas are taken from Hallberg (1980); WC = Whole Chena River (lower 152 km).

[b] Estimators are: SN = Schnabel; SE = Schumacher-Eschmeyer; P = Petersen (Ricker 1975); EXP = Expanded estimates (Clark and Ridder 1987b); EXP+P = expanded estimates and a Petersen estimate (Clark and Ridder 1988).

[c] Confidence is either the 95% confidence interval or the standard error (SE) of the estimate.

Appendix A4. Summary of Arctic grayling creel census on the Chena River, 1955-1958, 1967-1970, 1972, 1974-1989, and 1991.

Year	Dates	Area	Angler Hours	Harvest	CPUE	Mean Length
1955	ND	Lower Chena	---	---	0.89	226
1956	ND	Lower Chena	---	---	0.95	251
1957	ND	Lower Chena	---	---	0.62	246
1958	ND	Lower Chena	---	---	0.88	226
1967	4/10 to 8/11	Entire Chena	12,885	---	0.32	245
1968	5/01 to 9/02	Entire Chena	10,269	5,643	0.55	251
1969	7/01 to 9/30	Entire Chena	7,998	7,686	0.96	263
1970	5/01 to 5/30 and 7/01 to 8/31	Entire Chena	12,518	6,770	0.54	---
1972	5/25 to 8/27	Lower Chena	13,116	10,099	0.77	---
1974	7/01 to 8/31	Upper Chena	11,680	18,049	1.72	---
1975	6/01 to 8/31	Upper Chena	22,657	14,067	0.62	252
1976	6/01 to 8/31	Upper Chena	10,762	4,161	0.39	230
1977	6/01 to 8/31	Upper Chena	13,563	9,406	0.71	208
1978	5/29 to 8/31	Upper Chena	10,508	6,898	0.65	222
1979	6/01 to 8/31	Upper Chena	12,564	8,544	0.69	240
1980	5/08 to 9/30	Upper Chena	20,827	16,390	0.78	256
1981	5/01 to 8/31	Upper Chena	15,896	13,549	0.80	---
1982	5/01 to 9/15	Upper Chena	20,379	12,603	0.62	248
1983	5/01 to 9/15	Upper Chena	19,018	10,821	0.58	260
1984	5/06 to 9/15	Upper Chena	17,090	9,623	0.59	278
1985	5/08 to 9/05	Upper Chena	10,613	2,367	0.22	273
1986	5/10 to 9/15	Upper Chena	10,716	3,326	0.31	271
1987	5/18 to 9/15	Upper Chena	9,090	1,260	0.14	290
1988	5/14 to 9/13	Upper Chena	11,763	1,583	0.13	287
1989	5/19 to 9/13	Upper Chena	11,349	3,325	0.21	295
1991	5/18 to 7/31	Upper Chena[a]	3,201	---	---	280

[a] Only road km 43 through 73 of the Chena Hot Springs Road.

Appendix A5. Summary of age composition estimates of Arctic grayling in the Chena River, 1967-1969 and 1973-1992.

Year	Age 0		Age 1		Age 2		Age 3		Age 4		Age 5		Age 6		Age 7		Age 8		Age 9		Age 10		Age 11	
	p[a]	SE[b]	p	SE	p	SE	p	SE	p	SE	p	SE	p	SE	p	SE	p	SE	p	SE	p	SE	p	SE
1967	0.10	0.02	0.13	0.02	0.13	0.02	0.06	0.01	0.17	0.02	0.25	0.02	0.11	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.09	0.03	0.21	0.04	0.24	0.04	0.25	0.04	0.13	0.03	0.03	0.01	0.05	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.06	0.38	0.07	0.12	0.05	0.16	0.05	0.06	0.03	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.06	0.02	0.13	0.02	0.61	0.03	0.18	0.03	0.03	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.04	0.01	0.11	0.02	0.12	0.02	0.44	0.03	0.25	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.13	0.04	0.25	0.05	0.13	0.04	0.26	0.05	0.19	0.04	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.10	0.02	0.24	0.03	0.29	0.03	0.15	0.02	0.09	0.02	0.11	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.06	0.02	0.34	0.03	0.45	0.03	0.08	0.02	0.06	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.15	0.02	0.38	0.03	0.22	0.03	0.21	0.02	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.11	0.02	0.20	0.03	0.45	0.03	0.17	0.03	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.02	0.01	0.12	0.02	0.39	0.03	0.28	0.03	0.13	0.02	0.05	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.16	0.02	0.13	0.02	0.40	0.02	0.12	0.02	0.12	0.02	0.06	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.06	0.01	0.30	0.03	0.11	0.02	0.35	0.03	0.09	0.02	0.04	0.01	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.01	0.01	0.07	0.01	0.11	0.01	0.45	0.02	0.08	0.01	0.17	0.02	0.06	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.00	0.00	0.19	0.02	0.07	0.01	0.12	0.02	0.41	0.02	0.08	0.01	0.09	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.02	0.00	0.16	0.01	0.11	0.01	0.14	0.01	0.32	0.01	0.10	0.01	0.10	0.01	0.04	0.00	0.02	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.01	0.07	0.01	0.09	0.01	0.13	0.01	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.05	0.01	0.08	0.01	0.60	0.03	0.07	0.01	0.05	0.01	0.10	0.02	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.09	0.02	0.15	0.02	0.12	0.02	0.42	0.04	0.07	0.01	0.06	0.01	0.07	0.01	0.02	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.15	0.02	0.23	0.03	0.14	0.02	0.14	0.02	0.22	0.03	0.06	0.01	0.04	0.01	0.03	0.01	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.08	0.04	0.53	0.08	0.10	0.03	0.08	0.02	0.07	0.02	0.09	0.02	0.02	0.01	0.01	0.00	<0.01	0.00	<0.01	0.00
1991	0.00	0.00	0.00	0.00	0.08	0.01	0.11	0.01	0.52	0.02	0.11	0.01	0.07	0.01	0.06	0.01	0.04	0.01	<0.01	0.00	<0.01	0.00	<0.01	0.00
1992	0.00	0.00	0.00	0.00	0.14	0.02	0.20	0.01	0.15	0.01	0.38	0.02	0.05	0.00	0.04	0.00	0.03	0.00	0.01	0.00	<0.01	0.00	<0.01	0.00
1993	0.00	0.00	0.00	0.00	0.14	0.01	0.48	0.03	0.12	0.01	0.09	0.01	0.11	0.02	0.02	0.00	0.02	0.00	0.01	0.00	0.01	0.00	<0.01	0.00

[a] p = the proportion of the sample at age.

[b] SE = the standard error of p.

Appendix A6. Summary of mean length at age estimates of Arctic grayling from the Chena River, 1967-1969 and 1973-1993.

Year	Age 0		Age 1		Age 2		Age 3		Age 4		Age 5		Age 6		Age 7		Age 8		Age 9		Age 10		Age 11	
	n[a]	FL[b]	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL
1967	30	25	41	135	41	186	17	243	51	272	77	293	32	321	15	335	0	---	0	---	0	---	0	---
1968	10	73	24	103	28	150	29	214	15	255	3	289	6	304	2	372	0	---	0	---	0	---	0	---
1969	0	---	0	---	0	---	11	191	19	236	6	273	8	304	3	317	3	356	0	---	0	---	0	---
1973	0	---	11	111	25	167	121	194	36	215	6	279	0	---	1	310	0	---	0	---	0	---	0	---
1974	0	---	12	130	32	169	37	199	133	217	76	236	12	259	1	315	0	---	0	---	0	---	0	---
1975	0	---	0	---	12	171	22	200	12	229	23	238	17	258	2	275	1	320	0	---	0	---	0	---
1976	0	---	26	144	61	175	74	194	39	221	24	249	28	270	4	308	0	---	0	---	0	---	0	---
1977	0	---	14	112	77	176	102	208	19	245	13	263	4	299	0	---	0	---	0	---	0	---	0	---
1978	0	---	39	128	102	167	59	206	56	230	9	256	2	290	1	325	0	---	0	---	0	---	0	---
1979	0	---	25	107	44	165	99	197	38	236	11	266	1	310	0	---	0	---	0	---	0	---	0	---
1980	0	---	4	114	31	154	97	198	71	231	33	259	12	292	3	327	0	---	0	---	0	---	0	---
1981	0	---	61	112	48	162	152	187	46	215	47	240	22	268	5	287	3	310	0	---	0	---	0	---
1982	0	---	19	105	88	137	34	190	105	215	26	251	11	279	7	305	6	337	0	---	0	---	0	---
1983	6	62	33	114	53	151	215	177	38	216	83	239	29	273	13	307	7	338	0	---	0	---	0	---
1984	0	---	82	97	32	153	54	182	179	213	36	226	40	257	7	275	6	321	0	---	0	---	0	---
1985	0	---	42	108	300	141	203	188	267	215	609	233	182	285	188	285	80	308	30	377	2	377	0	---
1986	0	---	40	109	104	164	755	184	79	220	110	251	153	270	42	301	22	318	5	330	1	346	0	---
1987	0	---	0	---	54	160	92	204	691	228	115	274	76	292	184	309	30	324	31	338	2	353	0	---
1988	0	---	7	108	135	172	238	216	181	239	707	260	118	288	95	313	110	325	35	347	7	337	2	374
1989	0	---	17	123	285	156	295	215	205	254	245	272	423	285	112	314	73	329	54	347	5	372		
1990	0	---	13	129	134	174	840	207	232	251	223	280	221	298	284	308	63	332	43	340	17	362	2	359
1991	0	---	0	---	143	177	211	215	863	241	227	273	177	298	199	303	135	316	23	335	19	347	3	338
1992	0	---	0	---	224	165	384	209	450	239	1046	262	214	288	157	307	134	312	57	321	20	338	6	347
1993	0	---	0	---	172	167	605	207	252	248	243	274	282	286	58	313	55	322	32	341	13	353	4	348
Average		40		114		159		198		230		255		285		305		323		348		358		366

[a] n = sample size.

[b] FL = the arithmetic mean fork length in millimeters.

Appendix A7. Summary of Relative Stock Density (RSD) indices of Arctic grayling (≥ 150 mm FL) captured by electrofishing from the Chena River, 1972-1993.

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
1972 (2A, 2B, 6, DS) - 6/19-6/22[b]					
Sample size	1,392	42	3	0	0
RSD	0.97	0.03	<0.01	0.00	0.00
Standard Error	0.01	<0.01	<0.01	0.00	0.00
1973 (2A, 2B, 6, DS) - 7/3-7/19					
Sample size	176	7	0	0	0
RSD	0.96	0.04	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00
1974 (2A, 2B, 6, DS) - 6/25-8/15					
Sample size	889	58	0	0	0
RSD	0.94	0.06	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00
1975 (6) - 7/10-7/14					
Sample size	76	13	0	0	0
RSD	0.85	0.15	0.00	0.00	0.00
Standard Error	0.04	0.04	0.00	0.00	0.00
1976 (2A, 2B, 6, DS) - 7/19-8/6					
Sample size	613	59	1	0	0
RSD	0.91	0.09	<0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1977 (2A, 2B, 6, DS) - 7/5-7/30					
Sample size	916	30	0	0	0
RSD	0.967	0.03	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00
1978 (2A, 2B, 6, DS) - 7/10-8/11					
Sample size	841	20	0	0	0
RSD	0.98	0.02	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00

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Appendix A7. (Page 2 of 4).

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
1979 (2A,2B,8A,DS) - 6/26-8/23					
Sample size	802	13	0	0	0
RSD	0.98	0.02	0.00	0.00	0.00
Standard Error	<0.01	<0.01	0.00	0.00	0.00
1980 (2B,8A,DS,10B) - 7/1-8/15					
Sample size	1,260	53	2	0	0
RSD	0.96	0.04	<0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1981 (2B,8A,DS,10B) - 7/21-8/14					
Sample size	1,247	42	1	0	0
RSD	0.97	0.03	<0.01	0.00	0.00
Standard Error	<0.01	<0.01	<0.01	0.00	0.00
1982 (2B,8A,DS,10B) - 7/13-7/30					
Sample size	919	76	5	0	0
RSD	0.92	0.08	0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1983 (2B,8A,DS,10B,12)- 7/5-7/28					
Sample size	1,560	152	10	0	0
RSD	0.91	0.09	0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1984 (2B,8A,DS,10B,12) - 7/3-8/3					
Sample size	1,349	74	4	0	0
RSD	0.95	0.05	<0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1985 (2B,8A,DS,10B,12)-6/12-7/31					
Sample size[c]	ND	ND	ND	ND	ND
RSD	---	---	---	---	---
Standard Error	---	---	---	---	---
1986 (lower 152 km) - 7/7-8/6					
Sample size	1,268	160	29	0	0
RSD	0.87	0.11	0.02	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00

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Appendix A7. (Page 3 of 4).

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
1987 (lower 152 km) - 6/27-7/30					
Sample size	1,678	693	154	0	0
RSD	0.67	0.27	0.06	0.00	0.00
Adjusted RSD[d]	0.78	0.19	0.03	0.00	0.00
Standard Error[e]	0.04	0.04	0.01	0.00	0.00
1988 (lower 152 km) - 6/26-8/4					
Sample size[f]	1,855	1,242	217	0	0
RSD	0.63	0.32	0.05	0.00	0.00
Standard Error	0.04	0.03	0.01	0.00	0.00
1989 (lower 152 km) - 7/10-8/3					
Sample size[f]	1,363	1,340	184	0	0
RSD	0.47	0.46	0.06	0.00	0.00
Adjusted RSD[d]	0.57	0.38	0.05	0.00	0.00
Standard Error[e]	0.04	0.04	0.01	0.00	0.00
1990 (lower 152 km) - 7/2-8/3					
Sample size[f]	2,239	1,389	255	0	0
RSD	0.58	0.36	0.06	0.00	0.00
Adjusted RSD[d]	0.75	0.21	0.04	0.00	0.00
Standard Error[e]	0.17	0.03	0.01	0.00	0.00
1991 (lower 152 km) - 7/8-8/1					
Sample size[f]	2,587	1,185	178	0	0
RSD	0.65	0.30	0.05	0.00	0.00
Adjusted RSD[d]	0.73	0.24	0.03	0.00	0.00
Standard Error[e]	0.01	0.01	<0.01	0.00	0.00
1992 (lower 152 km) - 7/6-7/30					
Sample size[f]	2,068	949	102	0	0
RSD	0.66	0.31	0.03	0.00	0.00
Adjusted RSD[d]	0.78	0.20	0.02	0.00	0.00
Standard Error[e]	0.04	0.02	<0.01	0.00	0.00

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Appendix A7. (Page 4 of 4).

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>1993 (lower 152 km) - 7/6-7/29</u>					
Sample size[f]	1,370	613	84	0	0
RSD	0.66	0.30	0.04	0.00	0.00
Adjusted RSD[d]	0.79	0.19	0.02	0.00	0.00
Standard Error[e]	0.03	0.03	<0.01	0.00	0.00

[a] Minimum lengths for RSD categories are (Gabelhouse 1984): Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL; Memorable - 450 mm FL; and, Trophy - 560 mm FL.

[b] Year (sections sampled (taken from Hallberg 1980)) - sampling dates.

[c] Lengths were taken in 1985, but not reported in Holmes et al. (1986).

[d] RSD was adjusted to correct for bias due to the electrofishing boat (Clark and Ridder 1988).

[e] Standard error is for adjusted RSD only.

[f] Sample sizes do not correspond to RSD proportions because RSD proportions are weighted by abundance estimates in a stratified design (Clark 1989) and RSD is adjusted to correct for bias due to the electrofishing boat (Clark and Ridder 1988).

Appendix A8. Parameter estimates and standard errors of the von Bertalanffy growth model[a] for Arctic grayling from the Chena River, 1986-1988.

Parameter	Estimate	Standard Error
L_∞[b]	538	21
K[c]	0.10	0.01
t_o[d]	-1.72	0.11
$Corr(L_\infty, K)$[e]	-0.99	---
$Corr(L_\infty, t_o)$	-0.91	---
$Corr(K, t_o)$	0.95	---
Sample size	4,301	

[a] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_\infty\ (1 - exp(-K\ (t - t_o)))$. The parameters of this model were estimated with data collected during 1986 through 1988. This model was fitted to the data by nonlinear regression utilizing the Marquardt compromise (Marquardt 1963). The range of ages used to model growth was age 1 through age 11.

[b] L_∞ is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[c] K is a constant that determines the rate of increase of growth increments (Ricker 1975).

[d] t_o represents the hypothetical age at which a fish would have zero length (Ricker 1975).

[e] $Corr(x,y)$ is the correlation of parameter estimates x and y.

APPENDIX B
Data File Listing

Appendix B1. Data files[a] used to estimate parameters of the Arctic grayling population in the Chena River in 1993.

Data file	Description
U002ALA3.DTA	Population and marking data (first event) for Arctic grayling captured in the Lower Chena section of the Chena River (river km 0 to 72) 6 through 9 July 1993.
U002BLA3.DTA	Population and marking data (second event) for Arctic grayling captured in the Lower Chena section of the Chena River (river km 0 to 72) 12 through 15 July 1993.
U001ELA3.DTA	Population and marking data (first event) for Arctic grayling captured in the Upper Chena section of the Chena River (river km 72 to 152) 19 through 22 July 1993.
U001FLA3.DTA	Population and recapture data (second event) for Arctic grayling captured in the Upper Chena section of the Chena River (river km 72 to 152) 26 through 29 July 1993.

[a] Data files have been archived at, and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.